CANADIAN LAND RECLAMATION ASSOCIATION

ASSOCIATION CANADIENNE DE RÉHABILITATION DES SITES DÉGRADÉS

Conservation and Reclamation:

An Ecosystem Perspective

Canadian Land Reclamation Association's
21st Annual Meeting

Calgary, Alberta
September 18-20, 1996

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TABLE OF CONTENTS

LIST OF SPONSORS vi

INDUSTRIAL FACILITIES

Industrial Site Decommissioning in Alberta 1
Walter J. Ceroici

Changing Knowledge Needs for Wellsite Reclamation 3
Jim Smith

The Orphan Facilities and Pipeline Program: An Industry/Government Responsibility 7
David Lloyd and David Sandmeyer

In-Situ Amelioration of Sodic Mine Spoil Using Sulfur, Gypsum and Crop Management ... 11
Jeff J. Sansom, M. Anne Naeth, and David S. Chanasyk

Bioremediation of Contaminated Sites 13
Christopher Schneider

Contaminant Metal Concentration in Alberta Soils Under Different Land Uses 17
Gerry Lutwick, Gordon D. Dinwoodie, David Gower and G. E. Nason

Waste Disposal Guidelines from a Testing Lab's Perspective 19
John Ashworth

Reclamation of a Former Heavy Oil Plant in Northeastern Alberta 23
Tim R. Bossenberry, J. Jeffrey Wilson, David Evans, Darrell Chollak and George Walker

Nutrient and Metal Levels and Dynamics on a 30-year Revegetated Copper-Nickel Tailings Site at Copper Cliff, Ontario 27
Jeremy Niemi, John Giffen and Keith Winterhalder

FORESTS

Land Application of BCTMP Mill Waste Research in Alberta 31
Terry M. Macyk

Reclamation to Native Forest Ecosystems in the Oil Sand Region 33
Steve Tuttle

Land Capability Classification for Forest Ecosystems 37
Leonard A. Leskiw, Steve Tuttle and Earle Anderson

Forest Land Restoration on Vancouver Island 39
David Polster

Lichen Diversity in the Reclaimed Areas of Sudbury, Ontario 43
S. Wainio and Peter Beckett

MOUNTAINS

Application of Population Biology, Conservation Biology and Succession Theory to the Reclamation of a High Elevation Coal Mine 47
Clint R. Smyth

Plant Community Changes in Response to Anchor Chaining and Seeding on Pinyon/Juniper Sites in Central Utah 51
J. Gregory Sutor

Tailings Disposal and Reclamation at the Coal Valley Mine 53
Dane McCoy

In-Pit Disposal Program for Acid Generating Waste Rock 57
Jamie Quesnel and S. W. Stogran

Reclamation, Trans Canada Highway Twinning, Banff National Park 63
Otto Hammer

GENERAL ISSUES

Railway Reclamation: Issues and Opportunities 67
Chris B. Powter and David A. Lloyd

Experiences in Reclaiming Railways Under Alberta's new Reclamation Guidelines 71
Mark Polet

Pipeline Abandonment: A Discussion Paper 73
Karen Etherington

Legal Perspectives on Land Reclamation 75
Gilbert Van Nes

Liability for Reclamation: Enforcement at Common Law 77
Adrian Currie

WATER AND WETLANDS

Coursier Reservoir: The Planning and Costs Associated with the Reconstruction and Revegetation of a Subalpine Lake 81
J. Leah Jackson

Spray Lakes Reclamation Project 85
Margwyn R. Zacaruk

The Pine Coulee Project: Linking Reclamation Planning to Impact Assessment 89
Ron Middleton

Design and Construction Management Aspects of Constructed Wetlands 93
Bernard Amell and Kim Eastlick

Natural Revegetation of an Alberta Peatland after Horticultural Peat Extraction 97
Wayne S. Tedder and Larry W. Turchenek

RUNOFF/EROSION

Computer Modelling of Soil Erosion from Reclaimed Land 101
Les Sawatsky, Wes Dick and Senarath Ekanayake

Runoff and Sediment Yield under Grazing in Foothills Fescue Grassland of Alberta 103
M. Anne Naeth and David S. Chanasyk

Runoff Curve Numbers for Two Reclaimed Watersheds in Central Alberta 107
Ted E. Harms and David S. Chanasyk

Vegetation Characteristics, Grazing Disturbance and Soil Erosion 111
Suzanne I. Gill, M. Anne Naeth, David S. Chanasyk and V. S. Baron

PRAIRIE

Renewing the Ecological Integrity of Disturbed Native Prairie 113
Heather S. Gerling

Mixed Grass Prairie habitat Restoration Project: Landscape Restoration in the Moist Mixed Grass Prairie 117
Dean Nerberg

Native Prairie Regeneration After Pipeline Construction: A Comparison Between Topsoil Stripping versus No Topsoil Stripping During Construction 119
Gordon Dunn and Gina Fryer

Restoration of Native Sandhills Vegetation after Pipeline Construction in the Great Sand Hills Region of Saskatchewan 123
David G. Walker, Laurier Kremer and Wayne Marshall

The Effects of Grazing, Mowing, Glyphosate and Burning on Smooth Brome in Fescue Grassland 125
D. J. Brown and M. Anne Naeth

VEGETATION

Avoiding Downy Brome When Buying Seed 127
Kerby Lowen and Sarah Foster-Stubbs

Biodiveristy and Reclamation: How Many Species do we Need in a Seed Mix? 131
Dana Bush and M. Anne Naeth

Germination and Survivability of Selected Native and Introduced Grasses and Legumes 133
William E. Pelech and M. Anne Naeth

Road Maps for Repairing Ecological Damage 135
Andy Hammermeister

Ecovar Developments in Western Canada 137
Les Wetter and Brent Wark

Plant Growth on Aggregated Oil Sands Processing Wastes 139
Xiaomei Li, Jim Storey, Paul Y. P. Yeung and Martin Y. P. Fung

The Clover Bar Landfill: A State of the Art Landfill Reclamation Process 141
Ann Smreciu, Nolan Turner and Don Barron

BULK DENSITY

A Method of Characterizing the Bulk Density of Compressible Particulate Material 145
D. Guenther, Stacy Schaub and J. Leonard

Near-Surface Compaction Under Grazing of Annual and Perennial Forages 149
Dennis Twerdoff, David S. Chanasyk, M. Anne Naeth and V. S. Baron

Grazing Impacts on Bulk Density and Soil Strength in the Foothills Fescue Grasslands of Alberta, Canada 151
David S. Chanasyk and M. Anne Naeth

Computer Modelling of Soil Erosion from Reclaimed Land 155
Les Sawatsky, Wes Dick and Senarath Ekanayake

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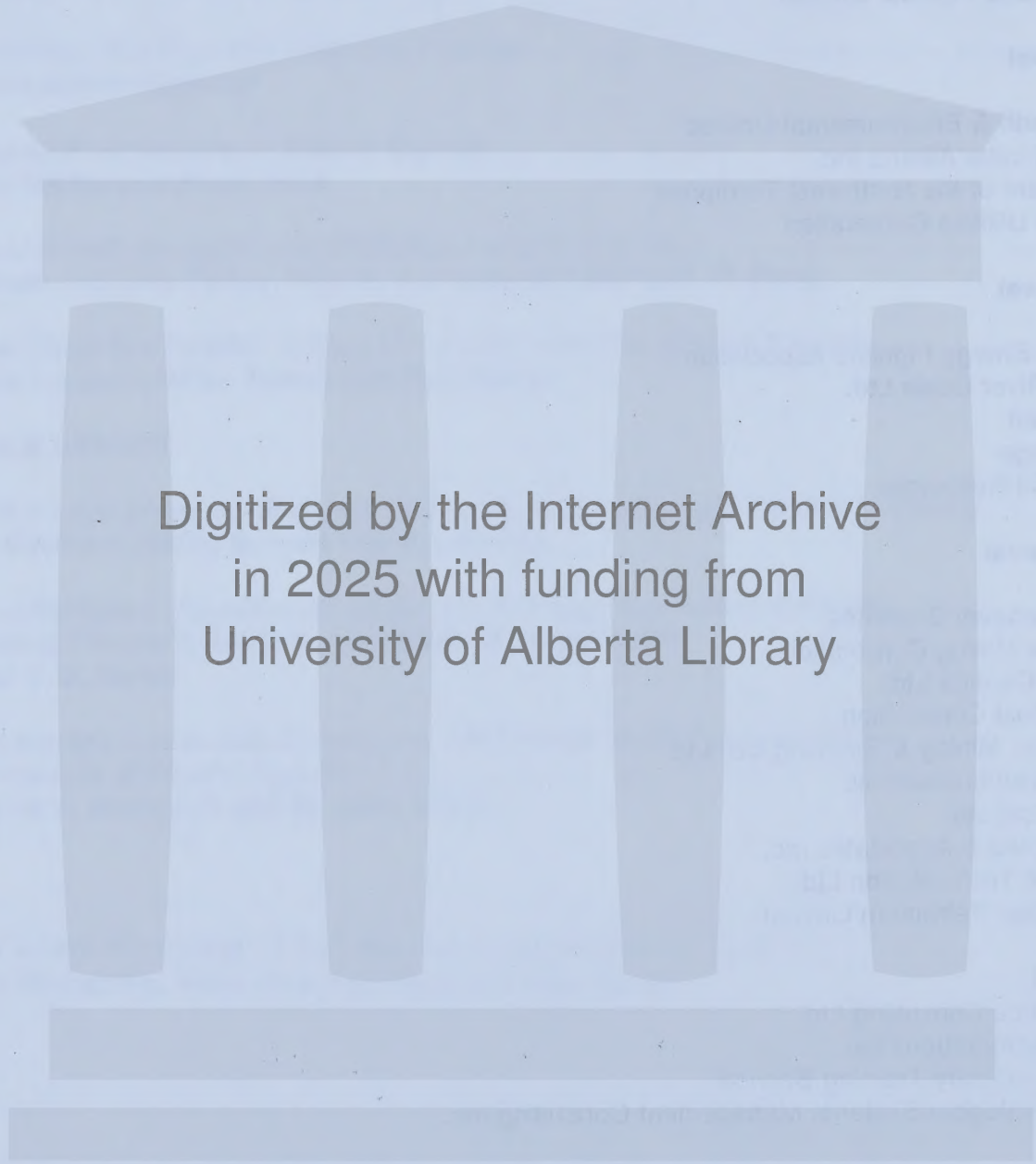

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INDUSTRIAL SITE DECOMMISSIONING IN ALBERTA

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Once an industrial facility reaches the end of its productive life it must be properly decommissioned to minimize the impact of any contamination on human health and the environment and to put the land into productive use. The process of decommissioning involves the takedown of buildings and equipment, termed abandonment, and the decontamination of a property. Typically, a site assessment must be conducted to determine the nature and extent of any contamination followed by the development of a remediaiton plan and confirmatory testing. An overview of regulatory and technical issues related to industrial site decommissioning in Alberta is presented.

*Presented at the 21st Annual Meeting, Canadian Land Reclamation Association, Calgary, Alberta, September 18-20, 1996.

CHANGING KNOWLEDGE NEEDS FOR WELLSITE RECLAMATION

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PURPOSE

One of the mandates of the Canadian Land Reclamation Association is to develop and promote education in the field of land reclamation. This paper will attempt to inventory the educational and informational sources available in this field and to do a qualitative check of their effectiveness. To ensure that the immense topic of reclamation is manageable, this paper will focus on reclamation of abandoned petroleum wellsite and related facilities within the province of Alberta.

INTRODUCTION

Within the last four or five years, most petroleum companies have recognized the need for an environment department. While this department varies in size from one person to a comprehensive staff, it is often assigned the responsibility for reclamation and decommissioning subsequent to many other pre existing responsibilities. Certain skills are necessary to have a properly functioning environment department. These skills are outlined below, although it should be recognized that these skill sets should not be expected in the same proportion across all of the various reclamation workplace positions such as management, field superintendent, contractors, etc.

Reclamation of abandoned petroleum surface leases requires the application of knowledge and experience from numerous fields or disciplines, many of which are grounded in physical science, others on social sciences. Fields of required expertise extend to agronomy, range management, soil science, agriculture, forestry, wildlife, environment, contaminant remediation, resource economics -- science in general. It requires application of knowledge of the production practices of agriculture, forestry or the land use within which the site is located; it may involve the application of knowledge of water management and/or remediation matters; it usually requires the need for sampling and analyses of various physical and chemical parameters. Technological expertise is required in understanding capabilities and outputs of various industrial processes, reclamation and agricultural equipment. Finally, an understanding of the legislative environment and the impacts of such legislation on stakeholders party to a site reclamation is essential. It goes without saying that an understanding of people component is imperative here as in many other fields of endeavour.

In some cases it is apparent that the combination of the necessary skills listed above are not present.

In addition to the need for formalized education opportunities for information and guidelines, those involved with reclamation reference various sets of legislation, regulations and constructs on which to base reclamation decisions and processes. A few of those elements are outlined here and are rated as either consistent or needing modification or harmonization to provide clarity and a more stable objective.

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* Presented at the 21st Annual Meeting, Canadian Land Reclamation Association, Calgary, Alberta, September 18 - 20, 1996.

CONSTRUCTS

Equivalent Land Capability: (ELC) *A situation where the ability of the land to support land uses after reclamation is similar to the ability that existed prior to an activity being conducted on the land. The ability to support individual land uses will not necessarily be identical after reclamation.*

RATING: THIS HAS BEEN THE CENTRAL OBJECTIVE FOR RECLAMATION ACTIVITY AND IS THEREFORE CONSISTENT.

Reclamation Criteria for Wellsites and Associated Facilities - attempts to satisfy the need for more objective criteria.

RATING: THIS IS CONSISTENT BUT STILL NEEDS SOME FINE TUNING TO ENSURE INTERPRETATION AGAINST ELC. THERE ARE CONCERNS THAT THE CRITERIA MAY BE UTILIZED AS GOSPEL RATHER THAN AS A GUIDELINE WITH THE OVERALL OBJECTIVE OF ELC CAPABILITY BEING SET ASIDE.

EDUCATION

Industry has recognized the need for enhanced educational opportunities in the field of reclamation. A cursory review of the response to such needs suggests that private, public and industry associations have been responding well. This review found many institutions offering reclamation related programs. Vermilion College, Olds College, Lethbridge Community College, the University of Lethbridge, the University of Calgary, the University of Alberta, NAIT and SAIT, have courses ranging from short-term extension classes through two year diploma and post-diploma programs, up to and including transfer programs and degree programs.

Two developments I consider worthy of particular mention are:

- In 1993 the University of Alberta restructured some of its traditional offerings through the Faculty of Agriculture to recognize the importance of conservation and reclamation by developing a related degree program.
- Olds College, Vermilion College and Northern Alberta Institute of Technology have collaborated in developing an applied degree in Environmental Management after a two year certificate at any of these institutions.

Private Sector and or Association education providers include the Environmental Service Association (ESA), and the Petroleum Industry Training Service (PITS), as well as a number of consulting firms. Over the last four to five years both PITS and ESA have offered more short term classes such as one to four day courses on various reclamation related subjects.

RATING: THIS PAPER THEREFORE FINDS THAT THE EDUCATION COMPONENT IS DOING QUITE WELL AND IS CONSISTENT.

PROFESSIONAL AND INDUSTRY ASSOCIATIONS

Alberta Institute of Agrologists, Alberta Society of Professional Biologists, and APEGGA all report increased numbers of members as listing reclamation as an area of professional practice. A joint conference was held last year, in part to foster communication and cooperation among these professions practising in the area of reclamation and environment. Other organizations such as the Environmental Services Association and the Canadian Land Reclamation Association serve the needs and interests of members and practitioners.

RATING: PROFESSIONAL AND INDUSTRY ASSOCIATIONS PROVIDE OPPORTUNITIES THAT ARE CONSISTENT AND IMPROVING.

LEGISLATIVE

Alberta Energy and Utilities Board / Alberta Environmental Protection
Jurisdictional issues between these two entities, particularly in the areas of oilfield waste, clean up of pits and ponds, etc., have lead to some confusion and occasional inconsistencies.
RATING: SOME FURTHER CLARITY AND HARMONIZATION WOULD BE DESIRABLE IN REDUCING CONFUSION ASSOCIATED WITH INTER JURISDICTIONAL RESPONSIBILITIES.

Alberta Tier I Criteria for contaminated soil assessment and remediation
RATING: THIS IS A CONSISTENT STATIONARY OBJECTIVE, WITH PROVISION TO GO TO TIER II.

Alberta Tier II - Risk Assessment based criteria
RATING: CONSISTENT IN PRINCIPLE ALTHOUGH THE PROCESS IS GENERALLY NOT WELL RECOGNIZED OR TRUSTED BY POTENTIAL PROPONENTS.

Tier I versus CCME Guidelines
RATING: ALBERTA AND FEDERAL GUIDELINES DIFFER. SOME HARMONIZATION WOULD BE DESIRABLE.

Alberta Environmental Protection Enhancement Act versus Surface Rights Act
APEA drives the requirement for reclamation of petroleum wellsites and sets conditions for certification. The Surface Rights Act governs the rights of access by petroleum operators onto privately owned or leased lands. Reclaimed sites can often benefit from a period of management and monitoring before certification. The Surface Rights Act has no provision, however, to support rental reduction on such sites during that interim period. Some landowners faced with the prospect of losing a $2500/year rental from a four acre wellsite have found cooperation in the reclamation process inconsistent with their best financial interests.
RATING: THERE ARE SIGNIFICANT INCONSISTENCIES BETWEEN SOUND RECLAMATION OBJECTIVES AND FINANCIAL REALITIES - NEEDS REVISION/HARMONIZATION.

Reclamation Criteria versus Common Law
If a farmer chooses to have a road or corral site built, then to sell the land, the purchaser is buying it as he sees it. However, if that same farmer asks a petroleum company to leave a road, pad, approach, culvert or whatever in place to accommodate his farming operations, several inconsistences can occur. First of all, AEP representatives can overrule the farmer's wishes and require removal of such facilities. Secondly, if the farmer chose to sell the farm, the purchaser could go back to the petroleum company and, with the support of AEP, insist on the removal of the facilities that the farmer had requested and which the operator had, in good faith, agreed to leave and or enhance.
RATING: CLEARLY THERE ARE SOME INCONSISTENCES BETWEEN RECLAMATION CRITERIA AND COMMON LAW THAT SHOULD BE ADDRESSED.

SUMMARY

Changing knowledge requirements in the area of reclamation practice require availability of current formalized education programs, clear legislation capable of providing objectives consistent with core constructs, and industry/professional associations dedicated to support and development of the industry. This review has found general consistency and support in the parameters examined, but has identified the need for modification/harmonization in several legislative or regulatory issues.

1

R.J. Mahnic, L.J. Knapik, T.R. Bossenberry and G.C. Mott, 1993. Proceedings of the Alberta Wellsite Reclamation Criteria Workshop. Alberta Conservation and Reclamation Council Report No. RRTAC 93-10.

THE ORPHAN FACILITIES AND PIPELINE PROGRAM: AN INDUSTRY/GOVERNMENT RESPONSIBILITY[1]

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PROGRAM HISTORY

The Orphan Well Program was established in December 1991. The program has been directed by a Fund Advisory Committee (FAC), made up of members from industry and the government, whose original task was to manage a formal process for abandoning all orphan wells in Alberta. Through the program, industry agreed to ensure that proper abandonment of orphan wells would occur without cost to the public or the government. An orphan well is one where the licensee or working interest owner(s) are defunct or missing and therefore not available to take financial responsibility for abandoning a well. The funds for completing the abandonment work have originated from an annual levy that has been collected by the Alberta Energy Utilities Board (EUB) from the oil and gas industry based on a fee for each inactive well. The Orphan Fund (OF) is a "restricted" fund that is administered by the EUB. Guidance for how the funds are used is provided to the EUB by the FAC. The Orphan Well Program for downhole well abandonment has been running successfully for two years.

In September 1994, a subcommittee was formed to establish an expanded process that would allow the FAC to add decontamination and land reclamation of the orphan wellsites to the downhole abandonment process already in place. The subcommittee was to consider all facilities and installations involved in the upstream oil and gas industry and make a recommendation about which orphan facilities the industry would abandon and reclaim under the fund. The recommendations submitted by the subcommittee have been accepted by the industry participants. Both government and industry participants have specific duties they must initiate and implement to ensure the program's success. The Orphan Well Program has now been renamed the "Orphan Program". ***The information presented is based on the proposal for the Orphan Program. Final implementation will depend on acceptance, by all parties, of the Orphan Facilities, Pipelines and Reclamation Subcommittee report .***

The focus of the Orphan Program is to minimize the risk of wells and facilities being added to the list of orphans, and to design, schedule and conduct a program to abandon and reclaim the existing and new orphans on a basis acceptable to industry and the government. To facilitate a minimized risk to the industry and the public purse, all multi-well facilities, both new and existing are to be licensed and tracked by the EUB.

FACILITIES TO BE COVERED UNDER THE FUND

The Orphan Program is to assume financial responsibility for Reclamation (Reclamation here denoted by the capital "R" includes abandonment, decontamination and land reclamation) of all upstream oil and gas installations. The expanded mandate not only includes facilities other than wells, but also adds complexity in terms of determining responsibility.

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*Presented at the 21st Annual Meeting, Canadian Land Reclamation Association, Calgary, Alberta, September 18-20, 1996.

*Présenté a la 21ème réunion annuelle de l'Association Canadienne de Réhabilitation des Sites Dégradés, Calgary, Alberta, September 18-20, 1996.

The upstream oil and gas wells facilities (both single and Multi-Well Facilities (MWF)) and infrastructure covered by the Fund include:

- wells
- single-well oil/bitumen batteries
- multi-well oil/bitumen batteries
- gas well facility
- group gas facility
- non-sulphur recovery gas processing plants
- pipelines (excluding transmission lines) - upstream of the producer's custody transfer point to a transporter/carrier
- produced water disposal facilities
- water/miscible flood injection facilities
- lease roads, and
- satellites

FACILITIES NOT COVERED UNDER THE FUND

The Orphan Program is designed to deal only with upstream oil and gas industry and installations (ie wells, facilities and installations prior to oil or natural gas entering major pipeline systems such as Nova, Interprovincial Pipeline and Peace Pipe transporters etc.). Further government/industry discussions are ongoing to determine appropriate programs for non-included activities. The non-included (downstream) activities concern refineries and sulphur producing gas plants that usually have an approval under Environmental Protection and Enhancement Act (EPEA). These activities are usually safeguarded by security deposits and specific approval requirements under EPEA

The facilities that are not covered by the fund include:

- any facility that is designated as being contaminated pursuant to section 114 of the Alberta EPEA
- oil sands mining plants and associated leases and infrastructure
- sulphur-recovery gas plants
- oilfield waste management facilities
- oil transmission pipelines and associated storage, pumping and measurement facilities
- gas transmission pipelines and associated compression and measurement facilities
- straddle plants, and
- refineries

LIMITING THE ORPHAN PROBLEM

Several administrative and legislative changes are recommended by the industry and the government to ensure that the population of orphan wells and facilities does not increase unnecessarily, to limit the financial risk to the Orphan Program and to ensure that orphan wells and facilities do not become a financial burden to the people of Alberta.

Administrative Changes and Requirements

There are new requirements being proposed for the industry and government that will change the way business is being done in the oil and gas industry. Some of the more immediate administrative changes are worth noting.

The EUB will require a license for all Multi-Well Facilities ("MWF"). To understand clearly what facilities exist, industry will be required to submit a "one-time" report for all active and inactive abandoned and uncertified MWF's. The one-time reports will be required within a specified time following announcement of the requirement to report. Consequences for delays in filing, failure to report, and making a false or incomplete declaration will be imposed on late or non-reporters. Regulations will require facilities and infrastructure to be safely suspended and subsequently abandoned within specified times of them becoming inactive. Decontamination and land reclamation must follow according to a plan and schedule. A refundable deposit will be required from the licensee where the timelines cannot be met for abandonment or reclamation. Transfer of a facility to another licensee will require approval form the EUB, as is the case presently for well licences. Inactive MWF's will be levied (similar to inactive wells) on a "per well equivalent" basis. This levy will provide the operating funds for the Orphan Program.

Operator ratings will be developed that will reflect the overall risk to the fund. Failing a rating will initiate certain consequences such as a doubling of the annual levy, a suspension of certain services by EUB and Alberta Energy (AE), and the issuance of orders to abandon by the EUB. Environmental Protection Orders (EPO's) could also be initiated by Alberta Environmental Protection.

Legislative Changes

Legislative changes will be required to fully implement the envisioned Orphan Program. Changes to both the Oil and Gas Conservation Act and the Environmental Protection and Enhancement Act will be introduced to provide corresponding requirements under both Acts so that the co-ordinated administration of programs may effectively limit the future of orphan wells facilities and infrastructure.

OPERATING THE FUND

Joint industry regulation or oversight of the Orphan Program will continue to be provided by an expanded Fund Advisory Committee (FAC) comprised of representatives from AEUB, AE, EP, Alberta Agriculture Food and Rural Development (AFRD), the Canadian Association of Petroleum Producers (CAPP) and the Small Explorers and Producers Association of Canada (SEPAC).

The Orphan Program is to be administrated primarily by the AEUB, an extension of the role they have undertaken with the current Orphan Well Program. Alberta Environment will be supporting the efforts of the AEUB and the Regulators will be sharing information, and co-ordinating regulation, oversight and enforcement.

Advisory committees of expert industry and government staff will provide continued review, assistance and advice to both the FAC and the AEUB on operating matters affecting the Orphan Program.

Any abandonment, decontamination and reclamation undertaken by the Orphan Program will be run by a "Program Superintendent" (PS). The PS will organize and direct the actual Reclamation work undertaken. The PS will be contracted jointly by the EUB, EP and AFRD based on a recommendation from the FAC, and under an FAC approved terms of reference. Authority for access and action on orphan sites will be given by government agencies, where required, to the PS. The PS will call for competitive bids for most work to ensure efficient operation of the program.

Where a party pays for the abandonment or reclamation of a well or a facility, he may apply for a defunct working interest participant's share of costs. The reserve portion of the OP fund that is funded by the levy is to be increased from $2,000,000 to $5,000,000 to cover off decontamination and surface reclamation.

SUMMARY

Industry and the government recognize that there are and will be facilities remaining with no viable responsible operators to abandon and reclaim a site. The Orphan Well Program was established by industry with a goal to ensure that orphan oil and gas wellsites were properly abandoned without leaving a liability to the public, the industry or to the government. The downhole well abandonment portion of the Orphan Well Fund has successfully started this goal. A second part of the orphan cleanup process has now been realized with the completion of a plan for the implementation of the decontamination and land reclamation portion of the orphan well program, now called the Orphan Program. It has also been recognized that the oil and gas industry is made up of a complex set of facilities that involve wellsites, pipelines, single and multiple well batteries, lease roads, satellites, processing plants and more. Tracking and enforcing industry compliance for abandonment and reclamation of these facilities has become a major task that the various government agencies have committed to working out with industry. The orphan well program that has operated for down hole well abandonment has demonstrated that the industry has the resolve and capability to take care of its legal and financial responsibilities. The newly developed Orphan Program demonstrates that the industry and the responsible government agencies are able to work together towards ensuring that all oil and gas facilities are properly abandoned and reclaimed.

IN SITU AMELIORATION OF SODIC MINESPOIL USING SULFUR, GYPSUM AND CROP MANAGEMENT*

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BACKGROUND

Salvaging and respreading topsoil and subsoil on recontoured minespoils is the dominant practice when reclaiming surface-mined land. Minespoils that are poor media for plant growth require a considerable thickness of suitable quality soil materials covering them to ensure adequate plant productivity. With sodic minespoils under semiarid conditions, 90 to 120 cm of cover soil is recommended by Powter et al. (1981). Such amounts of suitable quality soil material are often lacking in areas where sodic minespoils are found (Merrill et al., 1982). In addition, there are lands disturbed for reasons other than coal mining, not generally nor necessarily covered by soil replacement requirements, that need to be reclaimed (abandoned spoils, road cuts, water catchments, etc.). Thus the study of alternative reclamation techniques to subsoil salvaging and respreading for sodic soils are required. The application of calcium-supplying amendments is one such alternative. Another alternative is partial leaching of salts from sodic minespoils by increased soil water accumulation within the soil profile. In both techniques, an attempt is made to lower the elevated levels of exchangeable sodium in the minespoils, thus improving the chemical and physical properties of the minespoils necessary for successful revegetation.

MATERIALS AND METHODS

In summer 1991, experimental field plots, each 40 x 25 m, were constructed with unweathered sandstone minespoil from Pit 04 of the TransAlta Utilities Corporation Highvale Mine. Plots were in a split block with three randomized chemical amendment treatments (control, sulfur, gypsum) representing the whole plot and two randomized crop management treatments (fallow-barley, forage) representing the subplot components (Steel and Torrie, 1980).

The minespoil was sandy loam textured, calcareous, non-saline and sodic. As a result of the high sodicity, the minespoil was classified as unsuitable as subsoil in post-mining reclamation and thus, chemical amendments were added to ameliorate it. The spoil was amended with gypsum and sulfur at rates of application (18.25 tonnes ha^{-1} gypsum and 3,25 tonnes ha^{-1} sulfur) calculated to exchange 4 (Na) cmol kg^{-1} soil to a 35 cm depth below the topsoil. Amendment application was considered appropriate because cation exchange capacity of the spoil was low, averaging < 3 cmol kg^{-1}. Both gypsum and sulfur were cultivated into the spoil with three passes of a heavy duty disk followed by application of 20 cm of clay loam topsoil with a D11 crawler tractor.

In spring 1992, forage subplots were seeded at 25 kg ha^{-1} with rye (*Secale cereale* L.) as a cover crop seeded at 2 bushels ac^{-1}. The seed mix consisted of six forages varying in proportion by seed weight: alfalfa (*Medicago sativa* L.) (37%), smooth bromegrass (*Bromus inermis* L.) (37%), creeping red fescue (*Festuca rubra* L.) (3%) and Canada bluegrass (*Poa compressa* L.) (3%). At the same time, the fallow-barley subplots were seeded with fall rye. During mid-summer 1992, forage subplots were mowed and forage removed to simulate haying practices in the area; the fallow-barley subplots were sprayed with glyphosate at manufacturer's recommended rates and cultivated in the fall. For the remainder of the study (1993 to 1995), forage subplots were mowed in mid-summer. Fallow-barley subplots were cultivated to remove weeds each year except in 1994, when they were seeded to barley (*Hordeum vulgare* L.). The forage and fallow-barley treatments were imposed to provide contrasting soil water regimes.

RESULTS AND DISCUSSION

Overall, gypsum was more effective than sulfur at reducing sodicity (SAR) of this sandy loam minespoil due to the direct addition of Ca^{2+} ions. Although sulfur was also an effective amendment at reducing sodicity, it took a

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* Presented at the 21st Annual Meeting, Canadian Land Reclamation Association, Calgary, Alberta, September 18-20, 1996.

longer period of time to be effective since its reactions to produce Ca^{2+} ions were indirect and required microbial oxidation. Besides lowering SAR, both gypsum and sulfur affected other chemical properties in the minespoil. They lowered Sat% and pH, but elevated the concentrations of Na^{+}, Ca^{2+}, Mg^{2+}, K^{2+} and SO_4^{-2} in the upper (UAM = 20-35 cm) and lower (LAM = 40-55 cm) amended layers. In addition, gypsum affected these chemical properties in the manner just described above to a larger degree than sulfur and to greater depths. Only gypsum addition had an effect on soil moisture within the profile with less soil water at all depths. Although sulfur addition affected the same chemical properties, soil moisture in sulfur amended plots was similar to that in the control.

Crop management had no significant effect on reducing sodicity of this sandy loam minespoil. However, due to higher soil moisture in fallow-barley plots, soluble salts were leached to greater depths than in forage subplots. Crop management had a significant effect on the amount of soil moisture within the profile. Soil moisture was higher in fallow-barley subplots than in forage subplots. As well, crop management had a significant effect on penetration resistance (PR). PR was higher in the forage subplots than in the fallow-barley subplots; however, PR was unaffected by amendment treatments.

Both amendment and crop management treatments had no significant effect on organic carbon, bulk density, plant species composition, ground and canopy cover or annual biomass.

CONCLUSIONS

Sulfur and gypsum reduced SAR of the original recontoured minespoil (SAR > 20) to values as low as 3.9 in the UAM (20-35 cm) within 5 years. According to the suitability criteria for reclamation (Alberta Agriculture, 1987), this reduction changed the rating of the minespoil in the UAM layer from unsuitable (SAR > 20) to fair (SAR < 8) or good (SAR < 4) depending on the amendment and crop management treatment. Minespoil in the LAM (40-55 cm) remained unsuitable. Although amendment additions slightly reduced SAR in the LAM versus the control, the ameliorative effects were masked by the addition of salts (Na) from leachate water from the UAM. Thus more time is required for soil water to completely leach the salts out of the LAM.

The reduction of SAR was initially quite high after plot construction. In plots initially constructed of minespoils with SAR > 20, SAR ranged from 8.7 (gypsum treatments) to 13.7 (control) after only five months. However, after this quick reduction in SAR, further reductions throughout the study were small, particularly in the control. The unsuitable rating of the control plots remained relatively unchanged during the study, indicating that amendment addition was necessary to reduce SAR to improve its suitability classification.

In addition to chemical amendments, soil moisture was important in reducing SAR of the minespoil. Throughout the study, the premise that summerfallowing increased soil moisture within the soil profile resulting in elevated leaching and accelerating the reduction of SAR in the amended minespoil was supported.

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BIOREMEDIATION OF CONTAMINATED SITES

Christopher Schneider

Hydrocarbon contamination is commonly associated with abandoned wellsites. The cause of this contamination can be related to drilling waste material and/or the result from operations which took place on the site. Prior to the commencement of land reclamation, these sites often require an appropriate treatment to enhance remediation and degrade the hydrocarbon which is present in the soil. Landfarming is a recognized approach in the bioremediation of hydrocarbon contaminated soil. This land treatment method involves cultivating the soil surface and is normally aided with fertilizer amendment to provide a nutrient source for the microbial population involved in the degradation of hydrocarbon.

LANDSCAPE

The effectiveness of bioremediation will depend upon the prevailing environmental conditions in association with the landscape features. The site topography will influence the drainage capacity of an area including the degree of surface water runoff and any pooling or ponding condition. The site topography and parent material directly control the type of soil which will delevop on-site. It is known that the bioremediation is inhibited by anaerobic conditions which may occur on poorly drained sites. Sites that are sloped in addition to having pits or trenches to collect surface runoff water are preferable in maintaining adequate drainage.

SOIL PROPERTIES

The physical properties of a soil are an important aspect of bioremediation. The soil texture is an essential characteristic as it will determine the effectiveness of containment. There will be a tendency for hydrocarbon to leach or migrate downward into the soil if the percentage of sand is high. As the hydrocarbon components leach deeper into the soil profile, the soil environment becomes increasingly anaerobic. This will reduce microbial activity as well as pose mechanical difficulty in the landfarming operation. The macrostructure of the soil will also have a bearing as fissures may allow for the "escape" of oily material.

The introduction of hydrocarbon into a soil may affect the soil's wettability. For example, the infiltration of surface water into the soil profile is inhibited by the introduced hydrocarbon (i.e. the soil has poor wettability). This is often evidenced by a pooling condition that takes place on these sites. The reason for the development of this is that a thin layer of heavier oil film (being hydrophobic molecules) coats the individual soil aggregates preventing access of water and oxygen to the center of the aggregates (Rowell, 1977). This creates an anaerobic condition deleterious to microbial activity. In order for microbial activity to proceed under optimal conditions, there needs to be adequate aeration in combination with ideal moisture content. This displacement of air and water by hydrocarbon from the soil pores greatly influences degradation. In one experiment, the production of CO_2 from microbial respiration rose steadily as the oil content was increased to about 5.5% by weight; it dropped at about 8.5% (Schwendinger, 1968). These results suggest the problems associated with anaerobic conditions. In a landfarming operation, the incorporation of straw amendment is used to improve aeration.

Fertilizer amendment is used as a nutrient source for the microbes to "accelerate" the process of biodegradation. In particular, there is a requirement for nitrogen and, to a lesser extent, phosphorous and potassium in degrading hydrocarbon. The amount of amendment required and the appropriate ratio of N:P:K can be determined through soil testing. Under optimal nutrient conditions, the time frame for degradation will depend upon the percent hydrocarbon in addition to the soil properties.

Other soil properties that influence microbial activity include temperature, pH, and salt content. The additional of nitrogenous fertilizer is expected to have an acidifying effect on the soil. The pH level needs to be monitored as part of a land treatment program and, if necessary, lime incorporated to maintain the soil near an optimal pH of 6.5 (Toogood et al, 1997).

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CHEMISTRY

The hydrocarbon compounds identified in oilfield waste are degraded by a wide variety of microorganisms including bacteria, yeast, filamentous fungi, and actinomycetes. Bacteria appear to play a major role in degradation. There is substrate specificity and oxidation is found to be an inducible system (i.e. the enzymes involved in the initial breakdown are produced by the organism in the presence of the substrate) (Rowell, 1977). This is confirmed by the lag in microbial activity following introduction of a hydrocarbon source.

Once the initial reaction unique to the microorganism is initiated, the pathway to degradation follows a well characterized pathway such as B oxidation in the metabolism of alkane (this fraction accounts for a large proportion of the hydrocarbon present in most petroleum oils) (Rowell, 1977). The final products are normally carbon incorporated into the microbial cellular tissue or respired carbon dioxide. However, intermediate compounds may build-up if the environmental conditions are unsuitable or there are limiting nutrients. These intermediate compounds may leach into the soil profile allowing for selectivity of various components. The result is that the soil can act as a chromatography column (Plice, 1948).

The lighter chain hydrocarbon and aromatics cause varying degrees of toxicity to microorganisms. However, due to the properties of these molecules, there is a significant proportion lost to volatilization. The process of landfarming enhances the volatilization of these compounds through aeration.

It has been generally found that landfarming is a viable approach to the bioremediation of contaminated sites. However, several factors including landscape, soil properties, and chemistry need to be taken into consideration to ensure the success of this form of land treatment.

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CONTAMINANT METAL CONCENTRATIONS IN ALBERTA SOILS UNDER DIFFERENT LAND USES[1]

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Metal and metalloid elements occur in soils at varying concentrations related to composition of the earth's crust, variations in surface mineralogy and weathering processes. Some such elements in one or more chemical forms pose a toxic hazard to various life forms including humans, plants, animals and microbiota. At naturally occurring concentrations these elements rarely require management because they occur primarily in stable or metastable minerals that equilibrate with low bioavailable metal concentrations in the soil solution. However, elevated metal concentrations due to contamination degrade soil quality in part through raising the concentrations of bioavailable forms. Because geochemical backgrounds vary, it is usually of interest in a soil quality investigation to assess metal contaminant concentrations on a site-specific basis and in consideration of regional expectations.

Over the past few years Alberta Environmental Protection's Chemicals Assessment and Management Division has been collecting and interpreting both ambient and industrial point source data on contaminant metal concentrations in Alberta soils. Between 700 and 800 observations have been made on 12 metal concentrations in surface soils under ambient conditions. Samples for these analyses were drawn primarily from agricultural soils prior to regulated application of municipal sewage sludge (about 200 samples) and from a program designed to sample soils from throughout Alberta in five land use categories (about 600 samples) as follows: transportation corridors, new urban and old urban parklands, rural parklands and commercial sites. Several hundred observations on industrial site soil quality are also available from investigations conducted under regulatory approvals, primarily for chemical plants, fertilizer plants, gas plants, railyards, wood preservers and the metal industry.

Analyses to date have established the normal geochemical range and approximate distribution of the common contaminant metals in upland Alberta soils as well as an overview of the magnitude, frequency and nature of contamination under some land use applications.

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Distributions of contaminant metals under non-contaminating or minimally contaminating land uses - and located away from point of diffuse sources - are interpreted to represent geochemical background. Pooling data from the sewage sludge and ambient databases shows that many soil metals commonly follow an approximate normal distributions (e.g., Co, Cr, Cu, Hg, Ni, V and Zn), but distributions with varying degrees of right skewness are common also (Ba, Cd and Pb). Classical parametric statistics such as the mean and standard deviations have greatest meaning for the first group, but both groups can be discussed in terms of the cumulative frequency distributions. This is useful in considering data from more intense land use classes. For example, it can be estimated that the probability of a soil lead concentration in excess of 25 mg kg^{-1} occurring for reasons other than contamination is less than 0.01%. Contaminant metal data from the industrial site database generally shows the same fundamental geochemical distributions seen under ambient conditions, but these are augmented by points, spikes and clusters of higher values representing contaminant release to soil. Exceedance of geochemical background at industrial facilities is common for many metals, whereas exceedance of Alberta Tier I Criteria is less common and confined to certain metals. Observations exceeding CCME Commercial/Industrial criteria are relatively few and tend to be both localized and specific to the feedstocks and wastestreams characteristic of the particular industrial activity.

Two major conclusions from the work to date are: (1) prediction or determination of geochemical background at a particular site is normally straightforward and non-contentious; and (2) with few exceptions, Alberta industries are doing a good job of protecting on-site soils from severe contamination by toxic metals.

WASTE DISPOSAL GUIDELINES, FROM A TESTING LAB'S PERSPECTIVE

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SUMMARY

Analytical labs play an important role, both in site-assessment and in ensuring that waste materials are disposed of without harm to the environment. Labs are capable of rapid, inexpensive and accurate analysis of materials. Staff at testing labs are skilled and knowledgeable. Unfortunately, this laboratory expertise is seldom called on when guidelines for site and waste characterisation or disposal criteria are at the development stage.

The result of this neglect is often a guideline containing a set of analytical requirements which are inappropriate, either for the material being tested, or for the intended goal of the guidelines, or both.

Committees devising guidelines and recommendations involving analytical work are strongly advised to co-opt skilled technical members, preferably from laboratories who will be doing the testing. Government organisations involved in administering guidelines are strongly urged to include testing laboratories on their mailing lists, so that labs are not among the last to become aware of yet another new guideline.

INTRODUCTION

The term "guideline" as used here includes not only guidelines proper but also criteria, regulations, recommendations, informational letters, etc. A wide variety of guidelines exists, pertaining to waste disposal and site reclamation in the energy industry. Special attention will be given here to provincial guidelines relating to wastes from earthen pits and drilling sumps, and to oily wastes for disposal on roads. In discussing these, other relevant guidelines will also be considered.

THE PROBLEMS WITH GUIDELINES

Problem 1

With few exceptions, guidelines that require analytical work fail to give the full details needed by a laboratory in order to carry out testing. In most cases, guidelines give no details at all.

Problem 2

Guidelines may offer little, if any, background information or rationale for doing the analytical work that has been requested. Often, guidelines ask for analytical parameters that are either of no direct relevance to their main objective, or that increase the analytical cost or turn-around time far out of proportion to the amount of useful information gained.

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Problem 3.

Attempts by lab staff to resolve problems by consulting with the personnel involved in administering guidelines almost always meet with a dead-end. Typical responses are, in effect, yes our guideline is inconsistent or absurd but no, there is no easy way to change it; or, we have no technical expertise here so we have to leave the decision up to you lab people.

EXAMPLES

The good:

The latest draft of the Alberta Drilling Waste Disposal Guidelines (EUB, 1996) contains detailed instructions on sump sampling and analysis. It also tackles the problem of how waste disposal calulations are to be done in order to meet the stated criteria. The document is the result of co-ordinated efforts involving not only government and industry but also laboratory staff. No-one from any of these groups would claim that the document is perfect. It is certainly an inordinately long document; but most of the issues have been addressed squarely and relatively few inconsistencies remain. Best of all, from a lab's standpoint, there are comprehensive sections on analytical protocols.

Another example of a reasonably well thought-out set of guidelines is Alberta's municipal sludge disposal handbook (McCoy et al., 1982). The risks and benefits of land treatment of sewage are set out, and a rationale is given for characterising both waste and soil. Unfortunately, no analytical protocols are given by McCoy et al. However, these can be discerned from either analytical data or literature references also given in the document (though doing this of course requires an effort on the part of the laboratory).

The bad:

1. Lest anyone think Alberta Environment's ducks might all be in a row; requirements for assessment and remediation of earthen pits are described in cursory and sometimes contradictory terms (AEP, 1992; EUB, 1993 and 1994). Their requirements include on-site soil characterization "to the sub-group level" without elaborating on either the need or the means for achieving this goal. Fourteen "soil metals" are listed, including four which seldom if ever are a problem; namely arsenic (which incidentally is a non-metal) cobalt, manganese and strontium. "Oil and grease" (a wastewater analysis parameter) is specified for the solid contents of the pit. There are umpteen different ways to measure oil (or, if you insist, "oil & grease") but no analytical protocols are stated for this or any other parameter mentioned.
2. Saskatchewan Energy and Mines's drilling waste regulations (SEM, 1986) seem to have evolved gradually, so that different regulations apply in different parts of the province. For example, extra tests are required if the "sump fluid" - an undefined entity - has over 2,000 mg chloride per litre (1,500 in Newfoundland, sorry, make that Lloydminster).

Only in southwestern Saskatchewan (pity) calcium sulphate-based "fluids" may be spread off-lease at up to 90 m^3/ha if the EC is < 20 dS/m, but ammonium or potassium sulphate-based fluids at no more than 50 m^3/ha, if the EC is < 30 dS/m. No rationale is offered for these various numbers (there may well be one, but one is not on offer).

SEM's "extra tests" include both electrical conductivity and total dissolved solids, though the simple relationship between EC and TDS means you really only need one or the other, not both.

SEM may also ask for a "total metals" analysis (they don't state when or why they may, just that they may). Among the list of no fewer than 27 "metals" they may ask for are the non-metals arsenic (again), selenium and boron. Now, doing "total" boron gives a result (nearly always around 50 mg B per kg) that is quite meaningless, because only hot-water soluble B levels have been correlated with boron phytotoxicity. And throughout, no analytical protocols are on offer from SEM.

3. Country roads in Saskatchewan look very much like those in Alberta until, that is, you want to dispose of oily wastes on them, when they suddenly look very different. From the lab standpoint, one would far rather motor along in Alberta.

There, analytical methods are specified (at length) for a limited number of parameters in the waste as a whole. Also, an equation is given for calculating the rate of disposal. One would be quibbling to complain that the units of conductivity are given as dS/M and concentrations as mg/Kg, and that B is again called a metal.

But in Saskatchewan, the oil fraction of an oily waste is to be analyzed for a list of metals, separately from the water fraction. In a copy of the guideline, faxed to Norwest in June 1996, lead had been added to this list by hand. The water fraction is in turn to be analyzed for these same metals (oops, not forgetting that lead) plus other parameters, including phenols and sulphide (not boron).

Again, no methods are specified for either separation or analysis of the fractions, and no rationale is offered, in a brief (3 pages only) document.

The ugly:

For a story to fill lab kiddies with sheer horror, turn the pages of the British Columbia Drilling Waste Regulations. The testing lab is instructed by BC Energy, Mines and Petroleum Resources (1993) amongst other things to take the following steps:

- do a leachate extraction of the "sump fluid"
- do a 96 hour (= 4 days) fish test on this leachate
- measure boron in this leachate.

Since the "fluid" is defined by BC essentially as a "total waste" sample (as defined in Alberta; EUB, 1996) it may be almost entirely aqueous already, in which case a leachate extraction is meaningless (but a client may still tell a lab to do it, since it's a requirement). On the other hand if, as often happens, the sample has well-defined solid and supernatant phases, the technician then has to decide whether to (i) separate any solids and do a leachate on them, or (ii) do a leachate extraction of the whole fluid, or (iii) ignore the solids and just test the supernatant phase. The document, and BC's administrators, are equally unhelpful on these questions.

Shortly afterwards in this same BC document, a list of sludge analysis parameters appears out of the blue. The lab is asked to test this "sludge" for Biological Oxygen Demand, which:

- is a wastewater analysis, inappropriate for sludge
- requires a 5-day incubation period.

The BC guideline also gives a large list of other sludge analysis parameters, which might be nutrients, toxic metals, soluble ions, soil quality parameters or micronutrients, depending on how you look at it. However, one is not told how to look at it; again, no analytical protocols and no rationale are given.

CONCLUSIONS

Committees responsible for drafting guidelines which involve materials testing should include members with analytical expertise. Staff are usually willing to be co-opted from any one of a number of testing labs. It is after all in a lab's best interests to be aware of any new testing requirements. In any event, all labs should be on the mailing list for any guidelines.

New guidelines should include the reasoning behind the specified testing requirements. If this is provided, questions about why certain parameters have been included or excluded can be forestalled by the rationale given. This helps guidelines gain acceptance.

Guidelines should always include recommended analytical protocols, in detail, with appropriate documentation where possible. In this way analytical costs, turn around time and discrepancies can all be kept to a minimum.

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RECLAMATION OF A FORMER HEAVY OIL PLANT IN NORTHEASTERN ALBERTA

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INTRODUCTION

Canadian Occidental Petroleum Ltd. (CanOxy) has recently completed the decommissioning and reclamation of a former heavy oil pilot plant near Bonnyville, in northeastern Alberta. The Manatokan facility consisted of two former, non-contiguous pilot plant sites (Old Site and New Site), where heavy oil extraction was carried out with the aid of steam injection techniques. Small-scale, prefeasibility recovery operations were carried out at the Old Site, while large-scale, fully engineered petroleum recovery operations were carried out at the New Site. Activities at Manatokan were terminated in 1988. Decommissioning occurred between 1988 and 1995. Reclamation at the Manatokan sites began in the late fall of 1995.

Reclamation of the two sites proceeded under two different approaches, driven primarily by the quantity and availability of reclamation materials salvaged during construction of the sites. Topsoil had been salvaged during construction of the Old Site and was of sufficient quality and quantity for use in reclaiming that site. Topsoil had not been salvaged during construction of the New Site. The lack of any available surface soil required that a "new" surface soil be created, to enable successful reclamation.

Information from field investigations at Manatokan and treatability tests on soils collected from the New Site were used to design a reclamation plan that, when implemented, would return this former industrial site to an agricultural end land use.

FIELD INVESTIGATIONS

Most of the field investigations were confined to the New Site, since this is where most of the oil recovery operations occurred and where previous investigations identified petroleum hydrocarbon contamination. Also, a "new" surface soil would need to be created at the New Site; therefore, the quality of the soils on the new site would need to be compared to the quality of soils adjacent to the site.

Soils on the area adjacent to the "New Site" were characterised, and sampled and analysed for fertility, pH and organic matter content. The characterisation and analysis of these soils were used to determine the type and quantities of soil amendments and effort that would be required to recreate the soils on the New Site to an equivalent quality.

TREATABILITY TESTS AND RESULTS

To provide sufficient data to support recommendations for amending existing onsite surficial materials to allow successful revegetation a series of treatability tests were performed. Amendments, including local sawdust and manure, were added to samples of the clay-textured, organic-poor surficial materials taken from the New Site in a series of investigative laboratory tests. Information obtained from these treatability tests provided a benchmark for reclamation of the Manatokan sites.

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Treatability tests on the various sawdust/clay and sawdust/clay/manure blends included physical measurements (compaction, moisture holding capacity, consistence), chemical measurements (soil pH, electrical conductivity (EC), % saturation, soil fertility (available N, P, K), % organic matter), and biological measurements (seedling emergence and root elongation).

Upper subsoil amendment tests were conducted on samples to measure physical characteristics, using two volume ratios of clay to sawdust of 2.5:1 and 6:1, plus a control containing no sawdust. The samples were homogenised by removing all stones greater than 5 cm in diameter and hand-chopping the larger soil clods into more manageable pieces. The tests occurred over an 18 day period at a constant temperature of 20°C.

Results of the subsoil tests concluded that the 2.5:1 blend had a greater moisture holding capacity and a greater hydraulic conductivity, allowing for better drainage during wet periods, compared to the 6:1 blend and the unamended control sample. The 2.5:1 blend also had a more desirable consistence (friable), compared to the 6:1 blend and control sample (very firm and extremely hard) after two days of drying. The greater moisture holding capacity of the 2.5:1 blend was the controlling factor for consistence. An unconfined compression test was conducted on the subsoil samples to measure ease of fracture. The 2.5:1 blend at 14.3% moisture fractured the easiest, but again the ease of fracture, just as for consistence, is a factor of moisture content. All of the physical measurements indicated that the 2.5:1 blend of clay to sawdust is optimal for reclamation of the Manatokan site.

Surface soil amendment tests were conducted on samples to measure biological characteristics, using four volume ratios of clay to sawdust to manure of 10:1:3 (3.1% organic matter), 10:3:1 (6.2% organic matter), 10:2:2 (3.1% organic matter) and 12:1:1 (1.6% organic matter). The samples were homogenised by removing all stones greater than 5 cm in diameter and hand chopping the larger clods into more manageable pieces. The tests occurred over a 26 day period in a constant temperature room at 20°C, with a 16 hour light and 8 hour dark cycle. All samples were fertilised with a 20:27:5 blend of commercial fertiliser, watered and seeded with 21 barley seeds. The barley seeds were pre-tested for germination efficiency and were found to exceed 95%. Each sample was analysed for available nutrients, pH, total bacterial and fungal count, and moisture content. The barley plants were screened out of the surface soil samples at the end of the 26 day period to observe developed root characteristics. The screened soil samples were analysed for organic matter content, total organic carbon, detailed salinity, and residual nutrients.

Results of the seed germination and emergence tests concluded that the clay/sawdust/manure blends of 10:3:1 and 10:2:2 (>65% germination rate and rapid growth) were slightly better than the 10:1:3 blend (>45% germination rate and moderate growth) and significantly better than the 12:1:1 blend (<20% germination rate and slow growth). The difference in germination and growth is attributed to per cent organic matter, which controls moisture holding capacity. It was found that the 10:3:1 blend depleted the available nitrogen in the soil to a greater extent than the 10:2:2 blend, therefore, the 10:2:2 blend was recommended for optimum seed germination, emergence and growth.

RECLAMATION PLAN

The reclamation plan for the Manatokan sites was primarily directed by the end land use objective of returning the disturbed sites to an agricultural end land use, specifically domestic grazing. To meet this objective, the surface soil and upper subsoil needed to be reconstructed to enable a self-sustaining vegetation cover of mixed grasses and legumes to be established. The soils on site were reconstructed based on the treatability tests discussed in Section 3.0. The vegetation cover would need to be similar to the productivity of the adjacent grazing land, as measured by vegetation cover density, height, diversity of species and general health. The reclamation plan was implemented in five stages, each as discussed below.

Site Contouring

The two Manatokan sites were graded to a contour that: was stable; would allow for proper surface drainage; and would minimise interference with the use of agricultural implements, such as swathers and balers. A motor grader was used to contour the two sites. All large stones (>15 cm) were windrowed and picked from the sites.

Sawdust Application

Based on the treatability tests for recreating a new surface soil and upper subsoil, sawdust was applied to the New Site at a rate of 1000 m^3 per hectare. The sawdust was dumped in piles in a uniform grid pattern over the site and spread with a motor grader. After the sawdust was spread, the site was ripped to a depth of 30 cm to incorporate the sawdust into the clay. The site was ripped, cross-ripped and diagonally ripped to ensure thorough and uniform incorporation. A total of 5,120 m^3 of sawdust was applied to the New Site.

Manure Application

Based on the treatability tests for recreating a new surface soil, manure was applied to the New Site at a rate of 300 m^3 per hectare. The manure was spread over the New Site with manure spreaders and was rototilled to a depth of 15 cm to incorporate the manure into the clay/sawdust mixture. The New Site was rototilled end-to-end and side-to-side to ensure thorough and uniform incorporation. A total of 1536 m^3 of manure was applied to the New Site.

Fertilisation

Chemical based fertilisers were applied to the New Site to supplement the nutrient reserve in the surface soil and upper subsoil, allowing for sustained vegetation growth. An 11-51-0 (N-P-K) blend fertiliser was broadcast over the site at a rate of 150 kg/ha and incorporated into the surface soil and upper subsoil with the sawdust. Phosphorous will encourage the vertical elongation of rooting systems in the surface soil and upper subsoil. A 28-26-0 (N-P-K) blend fertiliser was broadcast over the site at a rate of 150 kg/ha and incorporated into the surface soil with the manure. Bacteria in the surface soil requires nitrogen to metabolise organic residues, such as manure and straw, that have been added to the soil. A slow release high nitrogen fertiliser will be broadcast over the New Site in summer of 1996 to encourage the growth of the grasses that have established.

Seeding

Grasses (Creeping Red fescue, Timothy, Crested wheatgrass, Smooth brome, Annual ryegrass) and legumes (Alsike clover) were broadcast at a rate of 50 kg/ha over the two Manatokan sites in the late fall of 1995.

MONITORING

The two sites at Manatokan were inspected in June 1996. The grass cover at the New Site varied from dense to sparse to none. The soil profile in each of these three types of areas was exposed to determine why the response by the grasses varied. The soil profile in the dense growth area was a 15 cm layer of clay, sawdust and manure overlying a 20 cm layer of clay and sawdust. This was the approximate profile created in the lab that had the best germination rate and sustained the best vegetation growth. The soil profile in the sparse growth areas was a 15 to 20 cm layer of clay and sawdust, with little manure overlying the clay subsoil. The soil profile in the no growth areas was a 20 to 30 cm layer of clay and sawdust, with very little to no manure content overlying the clay subsoil. Additional soil analysis (pH, EC, OM, available N,P,K and texture) performed on surficial soil samples from each area revealed no other apparent growth-limiting conditions, confirming that localized water-saturation following spring thaw contributed to poor seed germination in the affected areas.

CONCLUSIONS

Reclamation work at the New Site at Manatokan was not totally implemented according to the prescribed plan. Germination and sustained grass growth were good on certain areas of the New Site where the plan was properly implemented. Germination was poor to very poor and grass growth was sparse to very sparse, where too much sawdust was spread and incomplete incorporation into the surficial soils occurred. The excess moisture and unseasonably cool temperatures experienced in the Bonnyville area in the spring of 1996, combined with the high moisture holding capacity of the sawdust would likely have caused the poor germination on some areas of the New Site. The Manatokan site will be monitored again in the fall of 1996 to see if the sparse and very sparse grass growth areas have recovered.

NUTRIENT AND METAL LEVELS AND DYNAMICS ON A 30-YEAR REVEGETATED COPPER-NICKEL TAILINGS SITE AT COPPER CLIFF, ONTARIO[1]

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INTRODUCTION

On the western edge of the city of Sudbury, Ontario, exists the largest sulphide tailings compound in Canada. This compound, which is operated by Inco Ltd., has a total area of 5,500 acres (2225 ha) and began operation in the 1930s. Oxidation of the 5-10% of residual sulphide originally present in the tailings, combined with trace amounts of nickel and copper, make the tailings acid-generating and phytotoxic. Since the mid-1940s, attempts have been made to revegetate the tailings, the main goal being to stabilize the surface and prevent wind erosion. Today, most of the inactive tailings surfaces have been revegetated to some degree, with the older sites showing a relatively well established tree cover. The oldest of the revegetated sections in this complex is the so-called CD area, on which a vegetation cover has been established for up to thirty years.

The CD area is dominated by stands of white birch (*Betula papyrifera*), trembling aspen (*Populus tremuloides*), red pine (*Pinus resinosa*), and jack pine (*Pinus banksiana*). The deciduous species have invaded the area from the hilltops which protrude from the tailings surface, while the conifers were planted from the mid-1970s on. The other main plant assemblage on the CD area is herbaceous, predominantly of grasses and legumes, and is referred to here as the field community. This community has essentially developed from the grass-legume seeding carried out in the late 1950's. The present study examines the edaphic and vegetative properties of representative samples of the three main communities of the CD area - the field community, the jack pine community, and the white birch community.

METHODS

During the summer of 1995, soil properties, vegetative structure, and foliar metal and nutrient levels of the three selected CD area plant communities were examined. Soil samples were collected in two different ways, in order to establish both general properties and localized trends beneath the trees. Generalized soil properties were examined by collecting samples along a 100m transect in each of the three communities, at the following three depths: 0-5 cm, 5-10 cm, and 10-20 cm. These samples were then analyzed for pH, organic matter, particle size distribution, percent moisture, and total metal/cation content. For the more localized properties, six samples were collected from beneath each of the trees that had foliage sampled. The six soil samples were combined, then analyzed for pH and total metal/cation levels. All total metal/cation analysis was carried on an ICP spectrophotometer at the Inco Limited laboratory.

Vegetation was described in three layers, along the same transects used for the soil samples in the field, birch, and jack pine communities. The layers were: (a) the ground layer, which included all species less than one metre in height; (b) the shrub layer, which included all woody vegetation greater than one metre in height and having a diameter at breast height (dbh) of less than five centimetres, and (c) the tree layer, which included all vegetation greater than one metre in height and having a dbh greater than five centimetres. Percent cover, frequency and, for the ground cover, diversity indices were compared for the three different sites.

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[1] Presented at the 21st Annual Meeting, Canadian Land Reclamation Association, Calgary, Alberta, September 18-20, 1996.

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The metal and nutrient levels of the foliage were examined in jack pine needles and white birch leaves only. In the case of the jack pine foliage, needles from two consecutive years (1994-1995) were collected and analyzed separately. The birch leaves were only collected from the 1995 growing season. In each case, approximately 0.1g of plant material was analyzed for total metal and cation content. Leaves from similar vegetative stands on sandy soil at an uncontaminated control site near Sudbury were also collected and analyzed for comparison.

RESULTS

Soil Analysis

The pH values for all three plant communities on the tailings showed the same general trend, with the lowest values occurring at the surface and the highest values found at greater depth. The range of pH values in the birch community was from 3.65 to 6.13, with a mean of 4.58. For the field community the values ranged from 4.27 to 6.49, with a mean of 5.17, and the conifer community had a range of 5.4 to 7.71, with an overall mean of 6.71.

Values for mean percent organic matter were highest at the surface for all three communities. The overall highest surface soil values were observed in the jack pine community, with the average value being 10.2% organic matter. The lowest values were in the field community, where the average value was 6.5%.

Significantly higher mean copper and nickel concentrations were found in the surface soils of the field community (approximately 1,000 µg/g of each element), than in those of the birch and pine communities (approximately 400 to 800 µg/g). There were no significant differences between the surface soil metal levels in the birch and pine communities, although there was a trend in which copper tended to be higher in the birch community and nickel in the pine community.

Calcium values in the surface soils were significantly higher in the jack pine and field communities than in the birch community. The calcium values ranged from approximately 1.6% to 2.4%. Magnesium values were significantly higher in the surface soils of the field community than in those of the jack pine and birch communities. The magnesium values ranged from 1.4% to 1.9% for all sample depths and sites.

In the case of surface soil sulphur concentrations, the highest mean values were observed in the birch community (3938 µg/g) and the field community (3504 µg/g). Lowest mean values were seen in the jack pine stand (1046 ppm). In the birch and field communities, the sulphur level was slightly lower in the deeper soil, whereas under pines it was slightly higher.

Phosphorus levels were higher in surface soil than subsurface soil, and significantly higher under grasses than under birch at both depths

Vegetative Structure

The total percent ground cover was found to be highest in the field community at approximately 98%, and lowest, 68%, in the birch community. The percent litter cover for each of the three communities differed in that the birch site had an accumulation (38% litter cover), whereas the other sites had very little cover in the way of litter (2.5-5.5%). However, when comparing the species diversity of the ground cover between the three sites, the birch community had a higher diversity than the other communities.

With respect to the shrub layer, the jack pine community had no species which fitted this criterion, all woody species being members of the tree layer. The birch community had 122 shrub-sized individuals, which were represented by five different species, and the field community had 3 shrub-sized trembling aspens.

Foliage Nutrient and Metal Levels

Foliar copper and nickel were higher on tailings than at the control sites. Copper levels were higher in jack pine, while nickel was higher in white birch. Sulphur levels in birch were typical for the Sudbury region,

whereas those in jack pine were four times those in birch. In both species, manganese levels were 2 to 5 times higher in control leaves than in tailings leaves, despite the well-drained soil and the comparable soil levels at the control site

Foliar calcium and magnesium levels in birch were not significantly different on tailings and at the control site, but in jack pine both elements are significantly higher on the tailings. Despite the elevated level of some potentially toxic metals on the tailings, there were no visible signs of stress.

DISCUSSION

Although Inco Ltd.'s revegetation program has been successful in establishing an aesthetically pleasing vegetative cover on the CD tailings area, questions could be raised about the biodiversity and sustainability of the cover. In the jack pine community, no regeneration has occurred over the twenty-plus years since the trees were planted. However, in the birch community, the trees are actively regenerating, but a deep pad of leaf litter has developed, suggesting poor decomposition. Experiments are currently under way to investigate means of increasing both biodiversity and litter decomposition rate.

It is encouraging that, although there is evidence of elevated foliar metal levels, there are no visible signs of metal toxicity or stress.

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LAND APPLICATION OF BCTMP MILL WASTE RESEARCH IN ALBERTA

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INTRODUCTION

The sludge utilization portion of the Pulp and Paper Research Program at the Alberta Research Council involves three components including the Alberta Newsprint Company/Alberta Research Council joint research venture, landspreading ash and sludge at the operations of Slave Lake Pulp Corporation, and the ARC/ FIDB/ INDUSTRY research program. The research was undertaken to provide industry, government and the public with data that promotes an understanding of the effects of pulp mill waste landspreading and provides a basis for developing operating guidelines and protocols for landspreading (Macyk 1996).

The major activities included a review of the literature; waste stream characterization; greenhouse pot experiments; growth chamber experiments to measure the decomposition rate of sludges; column leaching experiments; and field landspreading trials.

LABORATORY AND GREENHOUSE TRIALS

Characterization work included determination of chemical and physical properties, saturated paste extract properties, DTPA extractable elements and total metals. Some differences were noted in the sludges generated by Alberta Newsprint Company, Millar Western Pulp Ltd and Slave Lake Pulp Corporation.

The greenhouse pot trials used conventional and de-ink sludges applied at the equivalent rates of 0 cm, 2.5 cm, 5 cm, 10 cm, and 20 cm. Fertilizer additions were based on the amount of sludge added and the respective amount of nutrients contained therein to result in equal amounts of nutrient added to all treatments (Macyk 1996). Brome grass, pine, and spruce were the three crops used. Four consecutive grass harvests, each after about a 90-day growth period were completed. The data indicated that the sludge amended treatments had consistently higher yields than the control. The pine and spruce in the sludge amended treatments showed more vigor, greater height growth and root mass than those in the control treatments.

FIELD STUDIES

The field studies involved the establishment of four controlled field experiments (Macyk 1996).

Slave Lake Pulp Corporation Site

A total of 18 individual plots each 6 m x 12 m were established at the mill site in June, 1992 (Macyk and Pojasok 1995). The treatments included control (0 cm) and layers of 1 cm, 3 cm, and 5 cm as well as a 5 cm/yr multiple application, and a combined 5 cm sludge and 0.5 cm wood ash treatment. Each treatment was replicated three times. The plots were tilled and brome grass was seeded.

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Soil samples were collected to a depth of 105 cm prior to sludge application and annually thereafter. Tissue samples were collected at the time of the first harvest in 1992, 1993, and 1994 and the entire plots were harvested to determine yield in 1992 to 1996 inclusive.

Grass yield increases were in proportion to increases in sludge application rate with mean yields as much as five-fold greater than control values for the higher sludge application rates. Yield responses to single sludge application have been evident for the five growing seasons.

Alberta Newsprint Company Sites

In May 1993, an agricultural field plot experiment was established near Mayerthorpe, Alberta with the variables including two sludges (conventional and de-ink), six application rates (0 cm, 1 cm, 3 cm, 5 cm, 10 cm, and a 5 cm/yr multiple application), one crop (brome grass) and three replicates. A total of 45 plots were established. Soil sampling to depths ranging from 105 cm to 3 m was undertaken prior to sludge application and annually thereafter (Macyk and Faught 1996).

Yields on the sludge amended plots were four-to-five fold greater due to the release of nutrients associated with the decomposition of the sludge and the improved moisture holding capacity. In June, 1993 a forest cut-block plot experiment was established south of Fox Creek, Alberta with the variables including the two sludges, four application rates (0 cm, 3 cm, 5 cm, and 10 cm), two crops (lodgepole pine and white spruce), and three replicates. Soil sampling was undertaken as described above.

The pine and spruce grown in the sludge amended treatments had increases in height growth as well as a deeper green color and more overall healthy appearance.

Additional experimental sites were established in disturbed forest locations including a haul road, oil and gas wellsite, and borrow area.

CONCLUSIONS

The land application research to date has provided data regarding the effects of landspreading mechanical mill sludges and a basis for developing guidelines and protocols for operational activities (Macyk 1996). The results indicate that:

1. Conventional and de-ink sludges are beneficial soil amendments.
2. Recommended application rates range from 40 dry t/ha to 80 dry t/ha depending upon characteristics of the sludge to be applied and receiving soil characteristics. Multiple applications should be considered.

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RECLAMATION TO NATIVE FOREST ECOSYSTEMS IN THE OIL SANDS REGION[1]

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INTRODUCTION

Suncor's reclamation goal is to achieve maintenance-free, self-sustaining ecosystems with capability equivalent to their pre-disturbed condition. This does not imply a changeless state, as landforms will experience the normal processes typical of the region leading to gradual reshaping of the landscape. Ecosystems are expected to evolve in revegetated terrain, from new plantings toward mature systems typical of those in the region.

Objectives of the Suncor reclamation program are:

- Disturbed lands shall be reclaimed with gentle slopes to primarily a forest use compatible with pre-disturbed terrain, providing a range of end uses including wildlife, traditional use and recreation; and
- Dyke slopes shall be revegetated primarily for erosion control providing natural end-use possibilities.

RECLAMATION PROCESSES

Development of a design to achieve Suncor's reclamation goals and objectives requires consideration of the principal processes influencing ecosystem development. The types of vegetation and soil that will develop on Suncor leases are dependent on climate, topography, parent material, drainage and time. In addition knowledge and experience gained from years of active reclamation work in the oil sands region provide specific design guidelines.

Suncor's vision for reclamation includes the construction of stable landforms and re-establishment of productive, self-sustaining ecosystems which will provide land use capabilities equivalent to those of the pre-mining environment. The greatest portion of the reclaimed landforms on the current and proposed oil sands mines will be returned to upland forest; the remaining will consist of shallow wetlands with some open-water areas.

As a result of constructed features, there will be a transfer of some of the land areas into alternate land forms. Some of the low lying land will be transformed into well drained slopes with a ratio of three vertical to one horizontal (3:1). These will be better drained than the pre-existing landforms and allow for the development of a more productive forest complex.

ECOSYSTEM RE-ESTABLISHMENT

Suncor has developed and successfully demonstrated its reclamation techniques for overburden and tailings sand deposits over the last twenty-five years. Soil reconstruction of disturbed lands provides the basis for establishing self-sustaining ecosystems capable of supporting a number of end uses. Prepared reclamation areas then undergo a single seeding of barley which serves as a nurse crop for out-planting nursery seedlings

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and other natural vegetation. Area fertilization is also undertaken for two to four years to establish adequate nutrient levels. Woody-stemmed species are planted in reclamation areas with species mix and planting densities defined by the specific ecosystem-type goals for the reclamation area and the variable terrain features of the area.

Soil Reconstruction

Suncor's current soil reconstruction technique has been used on an operational scale since 1984. Reconstruction of soil for reclamation areas is one of the critical components of Suncor's reclamation plan with ultimate capability of the reclaimed area determined largely by the quality of reconstructed soil. Reclamation sites are enhanced with quality soil-building material, using a technique which involves stripping muskeg to include 25% to 50% (by volume) of mineral overburden. The peat/till mixture (wherever possible containing live native vegetation) is hauled, placed on prepared overburden, tailings sand sites and spread to an average depth of 15 cm to 25 cm over the underlying materials. Stockpiling of muskeg soil is employed where surface disturbance has begun but where no areas are yet available for reclamation.

Revegetation Process

Typically, the revegetation process begins with excavation and hauling of undisturbed muskeg soils to the reclamation area. This method (which is completed in the winter whenever possible) enhances site revegetation because dormant, insitu native seed and root fragments are transferred with the soil. Spreading of the muskeg soil on the reclamation site is completed in early spring with the usual result an emergence of a variety of native, woody-stemmed species, forbs, wildflowers and grasses.

Revegetation objectives are achieved through implementation of a program which involves: seeding of reclamation areas with ground covers designed to control erosion; area fertilization; and establishment of appropriate, woody plant species. Suncor currently uses barley as a ground-covering nurse crop on all reclaimed sites. Barley (an annual variety) provides erosion control without hindering development of native vegetation emerging from the muskeg soil by leaving stubble which traps snow, thus protecting out-planted shrub and tree seedlings during the winter.

Fertilizer is applied during initial years of revegetation; applications are made from four to five years, depending on results obtained from annual monitoring programs. Yearly fertilizer application is then discontinued so that developing herbaceous cover does not compete too vigorously with planted woody seedlings.

Establishment of woody plants on reclamation areas is integral to the reclamation process. Selection of species and the proportion of each species in the planting mix are based on the woody-stemmed species common to the eco-sites within the Suncor region; existing field conditions; the vegetation type expected to develop on the site (based on landscape terrain features); and the expected growth of woody-stemmed species from seeds and root fragments in the soil amendment layer. Suncor's woody-plant establishment methodology is designed to accelerate the process of natural succession towards desired vegetation types. As woody cover develops on a reclamation area the micro-environment modifies, providing favourable conditions for later successional and mature species. The planting program ensures these species are present, established and capable of taking advantage of condition changes.

Woody plant seedlings are propagated either from seed or cuttings collected in the Fort McMurray area. Seedlings are planted in early spring and late summer, the choice depending on logistics and availability of reclaimed areas. Tree and shrub seedlings are planted at an average density of 2500 stems per hectare. This planting density is chosen to ensure sufficient seedlings are planted to permit establishment of volunteer plants and to provide adequate stocking of each species after initial mortality. Variation in woody-stemmed species planting ratios will allow a return of the original forest ecosystem in as short a time as possible. This revegetation mix will undergo natural succession processes and become a mature biological community providing habitat for wildlife as well as areas for traditional land use and recreation. Specific areas on the reclaimed site will have possibilities for timber production.

Primary Vegetation Communities

Four primary vegetation types found in the region are expected to develop as a result of Suncor's revegetation program:

- Closed Mixed-Wood Forest - Coniferous Dominant (Pine Forest) - This vegetation type will be established on the edges of tailings sand plateaus and slopes.
- Closed Mixed-Wood Forest - Deciduous Dominant (Poplar-White Spruce/Shrub) - This vegetation type will be established on the moister areas of tailings sand plateaus and consolidated tailings deposits. It will also be established on overburden dykes used to re-establish Steepbank Mine escarpment areas within the Athabasca River valley.
- Closed Mixed-Wood Forest - Coniferous Dominant (White Spruce-Poplar/Shrub) - This vegetation type will be established on the overburden dumps, the lower portions of the tailings dyke slopes with northerly aspects and on reclaimed consolidated tailings deposits.
- Wetlands Closed Shrub Complex - This vegetation type will be established on poorly- drained areas of tailings sand plateaus and consolidated tailings deposits.

MONITORING

Monitoring programs are instrumental in demonstrating that clear progress toward environmentally-sound and fully-mature ecosystems is being achieved as a result of the reclamation program implementeed at Suncor. Assessment of the sustainability of re-established ecosystems requires consideration of soil reconstruction, evaluation of revegetated areas, with forecasts of evolution of revegetated areas to mature systems. To determine this development, vegetation and soil characteristics in reclaimed areas are monitored each year. The monitoring program consists of annual vegetation cover assessment and soil sampling from areas reclaimed within the past three to four years, followed by detailed assessment and sampling of all reclaimed areas every fifth year.

Soils

Performance of topsoils and subsoils is a key parameter for ecosystem sustainability, and erosion control. Suncor has monitored and assessed its reclaimed soils by comparing trends of key parameters to reference soils. Results form the soil monitoring program indicate that the reclamation soils have sufficient nutrients to support an initial vegetative cover and improve in capability as they develop toward representative soils in the region.

Vegetation

The reclamation monitoring program assesses achievement of the reclamation objective of "returning the disturbed lands to a forested use compatible with pre-disturbed terrain, providing habitat for wildlife and with possibilities for recreation". Since 1976 Suncor has conducted programs to monitor ecological development on its reclaimed sites. Results of the reclamation monitoring program were recently summarized in the February 1995 Application for Renewal of Environmental Operating Approval (Suncor 1995a). Specific studies were initiated in 1995 to assess vegetation and soil characteristics of both reclaimed sand structures and natural forested areas on Suncor and Syncrude mining leases. The objective of these studies was to continue assessment of methods used to establish vegetation species suitable for erosion control and which develop into self-sustaining communities compatible with surrounding ecosystems.

CONCLUSION

Suncor's current method of reclamation and tree planting results in a diverse herbaceous cover developing within a year of soil amendment application providing erosion protection along with a source of cover and food for wildlife.

Ecosystems re-established on reclaimed sites will be self-sustaining and will function in a similar manner to ecosystems on undisturbed areas adjacent to the Suncor development. Individual components of re-established ecosystems have been evaluated as follows:

- Reconstructed soils have been shown to be equivalent to or better than original soils.

- Results of field monitoring indicate that Suncor's reclamation sites are developing into sustainable ecological units comparable to nearby natural forest areas. These results together with those from terrain modelling show that Suncor's reclamation strategy will achieve long-term, mature communities sustainable under current topographic and climatic trends.
- Successful development of a viable reclamation area vegetative cover together with establishment of reclamation drainage systems means that reclamation ecosystems will become viable wildlife habitats.

The characteristics and ecological diversity of reclamation areas will provide the flexibility to accommodate a number of end uses. Suncor believes that the reclamation plan and methods presented will meet the goal of achieving maintenance-free, self-sustaining ecosystems in the oil sands region with capability and plant community diversity equivalent to the pre-disturbed condition.

LAND CAPABILITY CLASSIFICATION FOR FOREST ECOSYSTEMS

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ABSTRACT

The Land Capability Classification System for Forest Ecosystems in the Oil Sands Region Manual (Leskiw 1996) is being applied to evaluate lands reclaimed to date by Suncor and Syncrude. In the process, the capability classification system will be tested and refined, and a comprehensive review of soil handling practices and resultant characteristics of reclaimed soils and their capability will be prepared (to be completed December 1996). Concurrently, a research project is underway to determine water holding capacities of tailings sand and peat-mineral soil mixes to confirm or revise values used in the classification system and to determine optimal mixes and depths for reclamation.

The foregoing will serve as a basis for planning and implementing future soil reclamation for forest ecosystems utilizing the "equivalent capability" concept of the Environmental Protection and Enhancement Act, on existing and proposed new mines in the Oil Sands Region.

The conference presentation features four natural and ten principal reclaimed profiles, their ratings, and implications of applying the capability system to future reclamation. These examples demonstrate how equivalent capability can be attained and measured. The numerical rating system is especially promising in helping to integrate the reclamation process within the companies, in enhancing communication among industry and regulatory stakeholders, and ensuring cost-effective, successful forest land reclamation.

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FOREST LAND RECLAMATION ON VANCOUVER ISLAND[1]

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INTRODUCTION

Forest land restoration has become a significant focus of the forest industry in British Columbia since the introduction of the Forest Practices Code (FPC) and the establishment of the Forest Renewal program (FRBC). Recognition of the ecosystem damaged caused by past harvesting practices has lead to demands by the public and subsequently by the regulatory agencies, for tighter controls on harvesting practices and for restoration of damaged systems. The science of silviculture, and hence reforestation, is reasonably well understood in situations where forest soils are intact and damage is restricted to loss of the original tree cover. However, where sites are significantly disturbed through construction of roads, landings and other industrial activities or by landslides, traditional silvicultural systems have failed to restore the forest cover and the function of the forest ecosystems.

Damaged and/or degraded forest ecosystems can have a significant impact on other resource values. Aquatic habitats and productivity have been significantly impacted by upslope harvesting. Heavy sediment loads resulting from erosion of upslope roads, trails, landings, landslides and other disturbances can bury spawning gravels and destroy fish habitat. Suspended sediments can affect community watersheds while changes in upslope hydrologic function can create flashy peak flows and scour otherwise stable riparian vegetation. Changes in the vegetation cover following harvesting can alter traditional wildlife use patterns and can affect the habitat of plants. These and other impacts place a strain on forest ecosystem balances and can have a drastic effect on other land and resource uses.

Restoration of forest lands seeks to establish a balance in the new forest ecosystems and thus the return of ecosystem function, both for the health of the forest and for the other values the forest ecosystems support. Steep slopes, heavy rainfall and low nutrient soils provide a challenge for restoration of forest lands on Vancouver Island. This paper explores a strategy for restoration of damaged forest lands based on natural successional processes. Successional reclamation (Polster 1991) seeks to restore the natural successional process which, given enough time, serve to revegetate disturbed sites. The establishment of an initial pioneering cover of vegetation is critical to the subsequent establishment of later successional species. Bioengineering, which is the use of living plant materials to perform some engineering function, can often be used to provide this initial cover by solving the physical problems which are preventing vegetation from establishing.

INITIAL COVER ESTABLISHMENT

Natural revegetation of naturally disturbed sites is often a slow process as pioneering species slowly gain a toe-hold in the generally harsh conditions following the disturbance. Although this process

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is generally slow, with pioneering plants such as mosses and lichens slowly building soils or species such as alder (*Alnus* spp.) and others ameliorating harsh site conditions, the processes which occur are essential to subsequent plant establishment. Successional reclamation seeks to identify those site features which are slowing or preventing the establishment of vegetation. On coastal forest sites these conditions typically include:

1) Excessive rainfall and rapid erosion which may wash seeds and young plants from the slopes before they can become firmly established.

2) The lack of soil or soil like materials, low nutrient status or excessive compaction may prevent or slow the establishment of vegetation.

3) Slope instabilities can prevent the establishment of vegetation through burial by materials coming from above or by continually sliding down the slopes prior to plants becoming fully established.

Amelioration of any or all these adverse conditions is the first prerequisite for successful plant establishment. Where soils are reasonable and slopes are stable, timing of the initial cover establishment can be critical to success. Traditional seeding programs must be scheduled to allow the seeded vegetation to become firmly established prior to heavy winter rains. Erosion rates of 300 to 400 tonnes/ha/year may be experienced on coastal sites and can result in loss of poorly established vegetation (Gray and Leiser 1982). Careful evaluation of long term climatic records can provide an indication of when there will be sufficient moisture for plant establishment and growth and when cool temperatures and/or heavy rains might prevent successful establishment (Environment Canada. 1993).

Sites where soils are lacking or where compaction or low nutrients are resulting in poor initial establishment can be treated in a variety of ways to provide an initial vegetation cover. Sites where previous erosion has resulted in loss of soil materials and the substrates consists of inert gravels and sands or exposed bedrock can be treated using pioneering species such as willows (*Salix* spp.), cottonwood (*Populus balsamifera* L.) alder and mountain avens (*Dryas* spp.) which can survive under very harsh conditions and will help restore a reasonable soil. On coastal sites, red alder (*Alnus rubra* Bong.) is particularly useful as a healthy mature stand of red alder can fix up to 80 kg/ha/year of nitrogen (Haeussler et al. 1990). De-compaction by ripping or other mechanical means can be the key to vegetation establishment on compacted sites (Moore 1994) while the use of fertilizers and species which enhance the nutrient status of the substrates can help on low nutrient sites.

Unstable sites must be stabilized for successful vegetation growth. Stabilization may entail significant geotechnical work on the site (Moore 1994). Bioengineering (Schiechtl 1980) can provide an effective means of stabilizing forest sites where instabilities are relatively minor. Wattle fences, which are short retaining walls built of living plant materials, can be used to stabilize steep, unstable slopes. Live pole drains, which are like "French drains" built of living materials, can provide drainage and assist in stabilizing moisture related instabilities. In both of these cases, the living materials used in the bioengineering construction sprout and grow, adding to the initial stability and providing conditions which foster establishment of later successional species.

Seeding is typically used in the establishment of an initial cover on drastically disturbed sites. The seed mix which is used must be balanced by seed weights so that the species composition allows for establishment of subsequent species (Polster 1991). This initial cover must provide space, both in the physical as well as ecological sense, for subsequent plant establishment and growth. Dense sod forming

mixes may be effective in controlling erosion, but may prevent the growth of woody species (Green 1982). Balancing seed mixes avoids this problem.

LATER SUCCESSIONAL SPECIES

The establishment of later successional species on the disturbed sites is relatively easy once the initial cover has been established and the natural successional patterns are re-established. In many cases, later successional species will quickly invade without further intervention if the sites are suitably prepared by the initial vegetation. In some cases, planting can be used to establish forest tree species. The work of the initial cover is to provide a suitable site for later successional species. Once this work is well under way, these later successional species can be easily established. Suitable sites for later successional species can be created by understanding the vegetation limiting problems associated with the site and mimicking the natural successional solutions to these problems. Once the site problems have been solved, natural successional processes will provide a self-sustaining, productive vegetation cover.

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LICHEN DIVERSITY IN THE RECLAIMED AREAS OF SUDBURY, ONTARIO*

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Abstract

The Sudbury Land Reclamation Program has been operating since 1978 and has treated about 25% of the heavily stressed land near the base mining and smelting complexes. In the subsequent years following reclamation over 20 species of lichen have invaded the ground in the developing open wooodland ecosystem. The most numerous lichens are members of the *Cladonia* ('Pixie cup') group but Reindeer lichens *(Cladina* spp) also occur. The pattern of invasion has similarities to that observed in other disturbed ecosystems (cutting or burning in forests, or abandoned farmland).

Introduction

The Region of Sudbury's Land Reclamation Program commenced in 1978 and has continued until the present time. Approximately 3500 hectares of acid metal-contaminated land have been treated, mostly with an application of dolomitic limestone, fertilizer and a grass-legume mixture (Lautenbach *et al.*, (1995)). Subsequently 2.75 million trees, using 17 species, have been planted with pines being widely used.

Since the late 60's there has been considerable improvement in air quality. Industrial sulphur dioxide emissions have been reduced by 90% and quantities of metal pariculate emissions have also decreased. There has been some natural recovery (*ie* without remedial assistance) of ecosystems in the Sudbury area (Gunn *et al.*, (1995)).

Lichens are good indicators of ecosystem health and in particular respond to air contaminants such as sulphur dioxide. With the change in sulphur dioxide concentrations there has been a response by lichens in areas not subject to land reclamation. Surveys (from 1968) of epiphytic lichens growing on Balsam Poplar

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(*Populus balsamifera)* demonstrate a reinvasion of the lichen desert once present around the smelters and the existence of pollution sensitive species (Leblanc *et al.* (1972); Beckett (1995); Gunn *et al.* (1995)). Field observations since 1978 have shown that following reclamation treatment there appeared to be a slow invasion of terricolous lichens into microsites created by the changes in vascular plant composition and cover. However, no systematic or detailed investigation had been made until the commencement of this study in 1995.

Sites and Methods

A series of sites on reclaimed land in the Coniston-Wahnapitae area, 10 km east of Sudbury, were chosen since there were several years of reclamation activity in a small geographical region. The sites span the years of operation of the land reclamation program and were picked to have similar landscape characteristics of gentle slopes above valley floors and stony substrates. Recently reclaimed sites, 1993, 1994, 1995, were dominated by grasses and legumes with few shrubs or trees except for small planted conifers. 1988, 1983, and 1979 sites have been invaded by a number of herbaceous vascular plants, poplar, birch and willow and have the appearance of an open woodland. Substrates were acid with a pH range from 4.5 - 5.5. For comparative purposes two sites in a logged pine forest (1978) and a burnt forest (1973) were investigated.

At each site three or four transects up to 5 m in length were marked. Along each transect a series of contiguous 20 cm by 24 cm quadrats were placed and percent cover of each lichen species measured. General vegetation characteristics and pH were determined.

Results.

The number of lichen species found ranges from 0 in 1995, 1994, 1993 to 17-21 at sites reclaimed in 1988 and earlier. Similar number of species were observed in the burnt and logged sites. There was no gradual increase in number of species over time. Likewise the overall coverage of lichens along the transects at the 1988 and earlier sites was around 40%. The burnt site showed a higher coverage of lichens (approximately 70%) and the logged site was similar to the reclaimed site.

Lichens observed belonged mainly to the *Cladonia* ('Pixie cup' group) with 19 species. There were no consistent patterns in cover but *Cladonia botrytes, C. cornuta, C. cristatella, C. gracilis and C. pleurota* were the most abundant on reclaimed sites. *C. cristatella* and *C. gracilis* were also abundant in the forest sites. The Reindeer lichens (*Cladina mitis* and *C. rangiferina* were present at all sites at and before 1988. *Peltigera canina* and *Stereocaulon* sp (both nitrogen fixers) were present in small amounts.

Discussion

Reclaimed sites contain a higher number of species than nearby barren or open birch woodlands where cover of *Cladonia. rei* > *C. cristatella*> *C. pleurota* > *C. botrytes*. *Stereocaulon* sp. is more abundant in untreated areas than on reclaimed land and may make a significant contribution to the nitrogen budget. No Reindeer lichens are found within 20 km of Sudbury (Beckett (1995)).

Intermittent field observations over a number of years suggested that the number of lichen species had increased with time. However in this investigation this observation was not supported since there were approximately the same number of lichens at each reclaimed site after several years. The sites were in the same geographical area and maybe once a lichen species had reached reclaimed land from outside the Sudbury area it quickly spread into all available microsites independent of time of reclamation. In abandoned fields it takes about 3 years for the first lichens to appear. Many species of *Cladonia* are abundant for the next 70 years and then start to disappear as the forest canopy closes (Hale (1983). On reclaimed land there were no lichens for the first three years following reclamation (1995-1993 sites). However at a 1992 location (not reported here) lichens were present and can be found at all sites back to 1979 (18 years after reclamation). Further observations are needed to see if lichens remain abundant or species composition changes as the trees begin to shade the soil.

The pattern of establishment is similar to that observed in other major disturbances in NE Ontario (fire and logging) and suggests that the detoxifying effect of limestone is beneficial to lichen establishment and successional changes. Since lichens are excellent accumulators of metals it is not surprising that elevated copper and nickel amounts (> 100 $\mu g/g$) are found in lichen communities in the Sudbury area (Cox (1993)). Whether amounts are less in lichens on reclaimed sites has yet to be determined.

Conclusion.

The effect of liming and grassing has provided suitable microsites for the invasion of lichens not otherwise present in the Sudbury area. The number of lichen species found approaches the number of vascular species found and if one were to include the bryophytes may exceed the number of vascular species. The policy of aiming for an open grass sward allowing for subsequent colonization has been successful in that plant biodiversity is large. It will be interesting to follow further lichen changes over time, especially in reclaimed area where the tree canopy is closing. Many of the observed species are characteristic of open or semi-open areas and may be replaced as the Sudbury reclaimed ecosytems continue to develop.

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APPLICATION OF POPULATION BIOLOGY, CONSERVATION BIOLOGY AND SUCCESSION THEORY TO THE RECLAMATION OF A HIGH ELEVATION COAL MINE[1]

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INTRODUCTION

Alternative reclamation approaches that involve 'minimal intervention' or aftercare may be necessary for high elevation disturbances. For these remote area disturbances, reclamation plans and practices should develop abiotic and biotic conditions that promote 'natural' succession by enhancing invasion and colonization of different microorganisms, plant life-forms and animal species (Brown and Chambers 1990). However, reliance on 'natural' restorative processes for reclamation is constrained by disturbance intensity and size (Pratt and Stevens 1992). Also, the successional status prior to disturbance and species in last occupancy often determines the most likely sequence of arrival and magnitude of colonization by invaders (Mortimer 1987).

Propagules arrive at potential growth sites by various dispersal processes and the configuration of donor sites or sources on the landscape determines frequently the distribution of propagules at the recipient site (Risser 1992). 'Natural' colonization from the periphery of disturbances is dependent upon the presence of sufficiently large populations of species with suitable life histories and the absence of dispersal barriers. Large surface mining activities frequently create landforms, e.g., highwalls and large spoil dumps, which do not have appropriate colonizing species in close proximity or which act as barriers to dispersal. Although colonization of these disturbances has been reported (Macyk et al. 1991), species establishment appears to be inconsistent. Since the recovery rate of primary succession is largely dependent on the rate of propagule arrival and on the reproductive potential of the invaders (Okansen and Ranta 1991), management techniques must be designed to maximize propagule dispersal.

Lessons from biogeography suggest that colonization by some desirable species cannot be left to 'natural processes' and that species with poor dispersal propagules and/or long life histories must be 'artificially' re-introduced (Davis 1986). Dispersal of both plants and animals can be facilitated by managing sites as 'corridors' or 'stepping stones'.

MANAGEMENT MODEL DESCRIPTION

Manipulation of populations is considered the logical choice for 'succession management' (Luken 1990). Therefore, a descriptive model was proposed and is being implemented at a coal mine in British Columbia. The core/satellite management model draws extensively on the stage-based population (metapopulation) dynamics of plants inhabiting patchy environments, metacommunity persistence and landscape ecology processes. The model can be visualized as an array of strategically positioned and intensively managed native seed production and/or wildlife habitat patches embedded within a matrix of seeded agronomic species. The model assumes that multiple disjunct foci or satellites which originate from the introduced or remnant patches (cores) and the adjacent undisturbed landscape will provide colonists for the matrix. In turn, colonization and expansion from the nascent foci (satellites) will facilitate the species replacement process within the matrix. The function of the matrix is soil development, erosion control and facilitation of fauna migration. Establishment of patches and the matrix are designed to be functionally integrated in order to maximize ecological interactions both within the disturbed area and between disturbed and non-disturbed areas. The model attempts to include, where possible, manipulation of all components of the successional process and is based on maximizing satellite colonization of the matrix by patch species as well as stimulating expansionary diffusion from patches. Incorporation of the spatial processes at the landscape level provides

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the opportunity for planning which facilitates colonization and migration throughout the entire post-mining landscape as well as through the adjacent undisturbed landscape. Plant-animal interactions and their manipulation are considered essential.

Relationship of Core/Satellite Colonization Model to Successional Theory

Conceptually, the proposed management model incorporates the theories of species colonization described by Moody and Mack (1988), the patch models of Cz<r<n and Bartha (1992), and the combined pool/corridor model of Merriam et al. (1990). The model is also analogous to the multi-cell loose equilibrium model of DeAngelis et al. (1985) in that it assumes that the entire system operates within a non-equilibrium status although metastability may exist at certain temporal and spatial scales. The non-equilibrium assumption of the model is derived from the low durational stability experienced by small patches (Pickett et al. 1989). The model assumes that persistent ecological entities such as patches have a minimal structure requirement (population size, patch structure and configuration) that permits persistence.

The descriptive model of Moody and Mack (1988) is the first component of the management model and describes the major mechanism of matrix colonization. Multiple disjunct foci or satellites originating from the introduced patches or, if present, from remnant patches or adjacent undisturbed lands, will provide the initial colonists of the matrix. Satellites may be the result of independent introductions from an initial source, of dispersal and repeated establishment of colonists from the initial source, or of a combination of both. The satellites are essentially metapopulations and could establish potentially during each growing season. The factors that contribute to the spread of invading plants are regulated largely by the dynamics of satellite stands rather than by the expansion of the initially large stand. Thus, the rate of spread of desirable species might be enhanced by concentrating resources, e.g., seed and fertilizer, to facilitate the development of satellites that could produce seed for natural dispersal. The establishment of 'intensively managed patches' of native species could function as nuclei for seed production and/or sources of propagules for the surrounding landscape and would facilitate plant successional development over the entire landscape. Furthermore, these patches would stimulate heterotrophic succession through the provision of wildlife habitat.

The model of Moody and Mack (1988) is most applicable, though not restricted, to species with more specialized mechanisms of dispersal where colonization takes place more as isolated individuals. Where the density of seed dispersal declines sharply with distance, it is likely that the population will colonize as an advancing front either through individual colonization or diffusion. The group of processes that involve dispersal or spread are different mechanisms from processes of diffusion where some attribute such as seeds or rametes are dispersed through a fixed population matrix.

The patch models of Cz<r<n and Bartha (1992) address specifically localized or smaller scale interactions of plant populations. The dynamics in this patch model are colonizations and extinctions within and between patches. Patch models assume that populations grow and interact in a number of finite topographical regions (habitat patches) which are separated by a continuous area (matrix) that is uninhabitable but more or less penetrable. Patch models also allow for population diffusion via small scale immigration of seedlings or clonal species expansion from the perimeter of patches.. This concept is important in the expansion and coalescence of patches at a more spatially restricted scale.

At the landscape level, the spatial relationships of the management model can best be described by a combination of the corridor and non-corridor models (Merriam et al. 1990). Corridor models assume patch connectivity and link logically plant succession with heterotrophic succession. Metapopulation size is related not only to quality of the particular patch and the number of other patches to which it is connected but also to the quality of adjacent patches. For those species requiring corridors, connectivity within the post-mining landscape would be facilitated by the continued existence of haul roads functioning as migration routes or as vectors between source and disjunct patches.

Patch Establishment - Plant Species Selection

Plant succession research indicates that the inclusion of different lifeforms (vertical and horizontal structure) in seeding and planting mixtures, together with appropriate amendments may increase phylogenetic

and structural diversity of revegetation communities and enhance rates of successional development (Chambers et al. 1988). Since the process of internal regulation is crucial to the maintenance of biotic diversity in ecologically isolated patches (Pickett et al. 1989), the 'functional group' selection and size of each patch must be based on ecosystem as well as metapopulation dynamics. Therefore, species with suitable 'vital attributes' (morphological, physiological, ecological) or those belonging to appropriate 'functional groups' are selected and combined to develop arrays of different 'biotic type' patches (metacommunities).

The accessions used in the metapopulation establishment should mimic the genetic variability of the donor population (Lippitt et al. 1994) in order to reduce the possibility of 'founder effects'. Re-established metapopulation numbers should approximate 10^3 - 10^6 individuals (Shaffer 1987), except where extant *in situ* (remnant patches) or *ex situ* sub-populations are within, or in close proximity to, the surface mine disturbance. In many cases, an effective population size of 500 individuals is adequate (Kesseli 1992).

Patch Establishment - Planning for Colonization and Dispersal

Knowledge of seed dispersal patterns and processes is essential to the spatial configuration design of patches within the matrix. Although reclaimed landscapes seldom correspond spatially to pre-disturbance conditions, there are commonalities which must be considered and planned for when implementing such a management program. 'Natural' as well as post-mining landscapes have spatial diversity with horizontal and vertical boundaries. Understanding the effects of landforms at the landscape ecology level is crucial to the development of a integrative reclamation program (Tueller 1992). As well, the incorporation of temporal and spatial processes external to the mine disturbance are fundamental to the long-term sustainability of reconstructed ecological systems under which minimal management intervention is anticipated.

From a 'controlled colonization' perspective, several management practices can increase propagule dispersal. The most obvious management activity is to increase recruitment by configuring the spatial arrangement of the patches within each landscape type (highwall, dump free face or platform) in order to reduce required seed dispersal distances and increase seed rain density. The direct placement of recently excavated topsoil onto disturbed sites as the pits 'daylight' in mountainous terrain might also re-establish patches of seed bank species.

Since the spatial distribution of species assemblages changes generally from early to later successional stages, replicating the later successional patterns during initial establishment may also enhance recovery. Plants established in 'correct arrays' may require little or no subsequent management due to efficiencies in moisture retention, nutrient availability and through sequestration of mobile inorganics and organics. The provision of suitable habitat for known seed dispersing fauna would facilitate seed dispersal of the appropriate plant species (Archer and Pyke 1991). Large ex-pit spoil dumps exclude effectively many proximal and distal colonists. Therefore, provision of migration corridors and alteration of landscape boundaries is necessary to make them more diffuse to biota migration and colonization (Sven-Olov 1990).

SUMMARY

Reclamation of high elevation surface mine disturbances is constrained by several factors, the most important of which is the availability of appropriate plant materials during the 'controlled colonization' phase. Therefore, 'managed natural' colonization has been proposed as an alternative. The management model is based upon maximizing satellite colonization of the matrix and on stimulating patch expansion.

Application of the core/satellite colonization model should increase beta and gamma diversity in reclaimed disturbances and stimulate heterotrophic succession.

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PLANT COMMUNITY CHANGES IN RESPONSE TO ANCHOR CHAINING AND SEEDING ON PINYON/JUNIPER SITES IN CENTRAL UTAH[1]

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ABSRACT

Pinyon/juniper woodlands occupy approximately 24.3 million hectares in the southwestern United States. Within the Great Basin and Colorado Plateau regions, the pinyon/juniper association was originally confined to steep, rocky slopes with poor soil development along the foothills and valley rim. Because of extreme grazing impacts from domestic livestock and suppression of naturally occurring wildfires, these woodlands have invaded far beyond their original niche. Areas that once supported productive grass-steppe communities are now dominated by a dense canopy of pinyon and juniper trees with very sparse herbaceous understories.

Over the past four decades, concentrated efforts to reclaim these invaded lands have been made. The technique of anchor chaining has proven highly successful in destroying a majority of mature trees and opening the community to recolonization of herbaceous and shrubby species. Anchor chaining consists of dragging anchor chains, commonly 60 to 150 meters in length, between two crawler tractors travelling in parallel directions. The heavy anchor chain uproots the trees as it passes across them. Various degrees of soil surface disturbances can be accomplished by use of varying sizes and appendages to the chain. In many instances this is used as a seed bed preparation technique.

A study conducted on four previously chained sites from 1960 to 1990 were evaluated to determine the difference in plant communities between chained and unchained sites. Comparison of community development through time as well as impacts of artificial seeding was also evaluated. Statistical differences in response to chaining, seeding mixtures and time since chaining were identified. Additionally, range sites, slope and aspect were identified as major factors in community response and development.

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TAILINGS DISPOSAL AND RECLAMATION AT THE COAL VALLEY MINE[1]

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ABSTRACT

Coal cleaning waste or tailings material is a waste stream generated by the processing plant at the Coal Valley Mine. The waste material consists of impurities that have been removed from the coal in order to meet customer specifications. The plant produces up to 1.5 million tonnes of coal cleaning waste annually. The waste has been characterized as coarse reject material and fine reject material. The waste streams have traditionally been separated during the process with the coarse material being dry and used in the backfilling of mined areas and the fine material being pumped as a liquid to mined out pits for disposal.

Previously, conventional tailings disposal used costly filter presses to dewater coal tailings. The resulting filter cake was hauled with trucks to a disposal site and the liquids were pumped to storage cells. Reclaiming these cells was difficult and expensive because up to six metres of material had to be placed over the tailings so that equipment could operate safely. Replacement of coversoil with a final 30cm cap over the rock was then completed and the area revegetated. Haul distances have increased and the cost of trucking has become prohibitive so alternatives to conventional capping were sought.

The current disposal method has eliminated the use of filter presses and production of filter cake. The coarse (dry) reject material is screened from the process and hauled to active mining areas for disposal and reclamation. The fine (liquid) reject material from the process is pumped in slurry form to a mined out disposal area. The current method of reclamation has eliminated the need to cap the tailings material with rock. The tailings material consolidates over time and after a period of dewatering, coversoil can be placed directly over the tailings material. This is carried out in winter when the upper part of the material is frozen.

Approximately 18 ha have been reclaimed using the new process. The various end land uses (forestry, wildlife, and wetlands) have d into the reclaimed landscape. Some of the area has been reclaimed successfully without the use of coversoil. The geotechnical, water quality and reclamation aspects of this experimental procedure show encouraging results and will be discussed in more detail.

INTRODUCTION

Innovative techniques for the disposal and reclamation of coal tailings at the Coal Valley Mine of Luscar Sterco (1977 Ltd.) and how they conform to the end land uses approved for the minesite are presented in this report. The Coal Valley mine is located approximately 90km southwest of Edson, Alberta in the Rocky Mountain Foothills. Current production of 1.7 million Clean Metric Tonnes of high volatile bituminous thermal coal which is supplied to domestic and export markets.

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The disposal of the coal tailings, particularly the fine materials (<0.5mm), has presented technical difficulties and costly options for handling and reclamation operations. The tailings have no economic value and their subsequent disposal increases overall production costs. Fine clays and ash material in the raw coal must be removed to achieve customer specifications. Special cleaning is required to remove the impurities to achieve customer specifications. The result is a process which generates both a coarse waste and a fine tailings stream. A two stage heavy media separation takes place producing a clean coal product, a middling product, and a coarse reject. The fine waste (<0.5mm) stream is difficult to handle and is the main focus of this paper. The past and present methods of disposal and reclamation will be discussed.

A research project was undertaken in 1988, using the old plant emergency tailings impoundment, to demonstrate, in various lab and field tests, alternatives to conventional tailings reclamation. The impoundment was the site of detailed geotechnical studies (Stahl and Sego 1992) (Thurber 1992) and biological studies (Macyk et al, 1991). The 18.2 ha area has been inactive for tailings disposal since 1989 when reclamation activities commenced. Results from this study area form the basis for future tailings reclamation where the principal objective is to reduce coal cleaning and reclamation costs, while maintaining the quality of the end product, which enables the mine .

SUMMARY AND CONCLUSIONS

Several aspects of tailings handling and reclamation have been investigated and changes have been implemented. The following summarizes this paper:

1. Processing and reclamation costs have been reduced by shutting down the filter presses, reducing the volume of semi solid wastes that require trucking, and changing the requirement for capping all tailings and rejects material with rock.

2. Coal tailings are capable of supporting adequate vegetative cover having similar vegetative characteristics to coversoiled areas. This may negate the need for 30cm of coversoil placement which in the past has been difficult and expensive to achieve even under frozen ground conditions.

3. Geotechnical results indicate that bearing capacities and shear strengths are increasing with time in the reclaimed areas including areas of reject fines. A number of natural surface processes particularly freeze thaw cycling has lead to the dewatering and strengthening of the tailings materials allowing vegetation to establish on tailings. Once established, vegetation will further aid in the dewatering and structural enhancement of the tailings as root zones develop.

4. The reclaimed tailings area blends into the natural landscape by incorporating approved end uses into the plan. A combination of forested land, wildlife habitat and wetlands can be created which will comply with existing operating approvals.

These studies were focused on reducing coal processing and tailings disposal costs. They have demonstrated that coal tailings can be reclaimed without capping the tailings with costly backfilling. The program also demonstrates that the area can be successfully reclaimed to a condition comparable to the pre-mining landscape ensuring long term sustainability.

The regulatory agencies have been extremely receptive to employing new and innovative technologies. The proposed changes are significant and without the foresight and willingness of the

regulators to participate, particularly Alberta Environmental Protection and Energy and Utilities Board (formerly ERCB), these changes would not have been possible. As such, companies in Alberta can employ new technologies and reclamation techniques allowing them to remain competitive and effective.

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IN-PIT DISPOSAL PROGRAM FOR ACID GENERATING WASTE ROCK

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ABSTRACT

For many years open pits have been used for the disposal of waste rock. Mine waste disposal has become an environmental issue that is watched closely by government agencies and the public due to the legacies of past mine waste disposal methods.

An in-pit disposal program for acid generating waste rock was conducted by Lakefield Research Limited at an abandoned mine site which operated as an open pit and underground mine. The mine was closed in 1975 and the mine property was included in a provincial park.

Prior to commencing the in-pit disposal program, an Environmental Site Assessment (ESA) of the mine property was conducted. The data collected during the ESA was used to develop a reclamation program that would address the site specific conditions that would maximize the on site resources to minimize the costs of the reclamation program. The ESA included: 1) a site reconnaissance; 2) sampling and testing of the waste rock; 3) sampling and testing of the surface water on site; 4) sampling and testing of the surface water background; 5) sampling and testing of the open pit water; 6) the construction of test pits along the access roads to establish the depth of the waste rock and for sampling procedures; and, 7) a topographic survey of the mine site.

The data from the testing program was used to determine the acid generating potential of the waste rock and the surface water quality. Two locations containing waste rock had started generating acid which had not generated acid at the time of closure, in 1975. One location contained an acid generating waste rock dump at a ramp location. In addition, the access road to the ramp area was constructed of acid generating waste rock. The second location was along the shore of a river, where acid generating waste rock had been used for construction of an access road for a pump house. The water quality of the pit water was acceptable and there was no evidence of the pit wall rock degrading the water quality. The water quality data of the pit water determined that a volume of the pit water could be discharged to the environment prior to placement of the waste rock.

Prior to the field program, the effect of placing the waste rock into the flooded open pit was determined by completing a laboratory column test with the waste rock and the open pit water. The results of the program were used to help predict any changes in water quality that would occur during dewatering of the open pit and waste rock placement.

From the results of the test program an in-pit disposal program was conducted for the waste rock. The acid generating waste rock was effectively disposed of in the flooded open pit using a simple underwater disposal method.

INTRODUCTION

There are four major concepts that have been used for the in-pit disposal of acid generating waste rock and these are: 1) underwater disposal, 2) elevated water tables, 3) dry disposal, and 4) perched water tables (Senes, 1995).

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It should be noted that in-pit disposal is not suitable for all types of waste material or for all open pits. Many technical factors would determine the appropriate method of disposal. Some of the factors follow: (Senes 1995).

1. the acid generation potential of the pit walls and the waste rock;
2. the geotechnical characteristics of the pit walls;
3. the underground development at the open pit location;
4. the surface water, pit water and ground water quality; and,
5. the hydrology and hydrogeology of the open pit.

An in-pit disposal program for acid generating waste rock was conducted by Lakefield Research Limited at an abandoned mine site which had operated as an open pit and underground mine. The mine was operational from 1969 until its closure in 1975. The mine property was included in a provincial park subsequent to its closure.

Prior to commencing the in-pit disposal program, an Environmental Site Assessment (ESA) of the mine property was conducted. The data collected during the ESA was used to develop a reclamation program that would address the site specific conditions that would maximize the on site resources to minimize the costs of the reclamation program. The ESA included: 1) a site reconnaissance; 2) sampling and testing of the waste rock; 3) sampling and testing of the surface water on site; 4) sampling and testing of the open pit water; 5) the construction of test pits along the access roads to establish the depth of the waste rock and to collect samples; and, 6) a topographic survey of the mine site.

Once the ESA was completed the mine plans were reviewed. The primary focus of the review was to assess the layout of the open pit, determine the ideal location for end dumping the material and locating the deepest area of the open pit. The underground development was also reviewed to determine if the underground development had advanced under the open pit. The pit wall stability was evident.

ENVIRONMENTAL SITE ASSESSMENT

There appeared to be no known stability problems as the pit was idle for the last 20 years without a known pit wall stability problem. In addition the water quality of the pit water was within the provincial water quality objectives and there was no evidence of degradation of the pit water quality from the pit wall rock. It appeared that the open pit was suitable for a Simple Underwater Disposal (SUD) method.

Two areas were discovered during the ESA that contained acid generating waste rock. One area was called the "F" zone which contained approximately 21,584 tonnes of potentially acid generating waste rock. The primary area of focus was the 'F' Zone ramp location and to the west of the existing swamp area including the access road. The second area, known as the Pumphouse Road, contained approximately 7,700 tonnes of acid generating waste rock.

ANALYTICAL TESTING & RESULTS

Waste rock and water samples were collected in 1994, by the property owners, in accordance with a protocol provided by Lakefield Research Limited. These samples were analyzed and the data was used in determining the chemical characteristics of the surface water and the waste rock. A bulk water sample from the open pit was retrieved for a laboratory column test to simulate the placement of the acid generating waste rock into a flooded open pit.

Surface Water Quality Testing

Twelve surface water samples were collected to chemically characterize the quality of the water at designated locations. The water samples were tested for pH, acidity, alkalinity, and conductivity. An Inductive Coupled Plasma Emission Spectroscopy (ICP-ES) total metal scan and sulphate analysis were also performed. The results of the tests were compared to the Manitoba Surface Water Quality Objectives (Class

1- Domestic Consumption and Class 2 - Aquatic Life and Wildlife). The Manitoba Surface Water Quality Objectives lists a Class 3 - Industrial Consumption category, but this class was not used as it is site specific and no guidelines were issued for surface water quality objectives at the site in question. Class 1, Domestic Consumption, defines objectives that ensure the protection of waters that are suitable for human consumption, culinary or food processing purposes as well as other household purposes. Guidelines for the Manitoba Class 1 Water Quality Objectives also state that changes in water quality due to human influence should not cause an unacceptable increased risk to public health or an unacceptable increased treatment cost to the water user or supplier. Class 2, Aquatic Life and Wildlife, objectives have been established to ensure the protection of streams, lakes, marshes, swamps, lowlands, and any other aquatic community or wildlife which may rely upon the surface water for habitat and or food supply. These objectives also ensure the passage, maintenance and propagation of fish species and additional flora and fauna which are indigenous to a cool water habitat.

Monitoring station 144-100, which is upstream of the mine site on an adjacent river was used as a background station. Comparison of sample data collected from the monitoring stations 144-111 (downstream of creek mix zone at the river), 144-105 (old pumphouse location at the river, upstream of the access road) and 144-106 (old pumphouse location at the river, downstream of the access road) with monitoring station 144-100, indicated that the mine site did not cause a major impact on the receiver (the river). However, the data also indicated that there were small localized impacts.

Data from a monitoring station located at the toe of the waste rock at the "F" Zone, suggested that there was an impact on the small pond at the toe of the waste rock. Higher concentrations of some metals were noted at this location than at other monitoring stations. The conductivity, sulphate, sulphur and iron were also higher at this location than at other monitoring stations. The pH (2.86) noted at this monitoring station was lower than the pH noted at the other stations. Field observations also note a visual difference at this location, as the water was a brown tea color and evidence of hydroxide precipitate was present. The data from the downstream monitoring stations showed a decline in heavy metal concentrations downstream of 144-104.

The water quality of the pit water was acceptable and there was no evidence of the pit wall rock degrading the water quality. From the pit water quality data, it was determined that a volume of the pit water could be discharged to the environment prior to placement of the waste rock.

Waste Rock Testing

The data from the testing program was also used to determine the acid generating potential of the waste rock. Two locations containing waste rock had started generating acid, which had not generated acid at the time of closure, in 1975. One location was an acid generating waste rock dump at a ramp location ("F" Zone). In addition, the access road to the ramp area had been constructed of acid generating waste rock. The second location was along the shore of the adjacent river, where acid generating waste rock had been used for construction of an access road for a pump house.

Eleven composite waste rock samples were collected to chemically characterize the quality of the waste rock at designated locations. The samples were tested for acid generating potential by using the B.C. Research Initial Static Test.

The following guidelines were used to evaluate the waste rock samples collected and to identify the materials which were potentially acid generating. Materials with an ACA/APP ratio greater than 4 were not considered to have acid generating potential. Materials with an ACA/APP ratio less than 1 were considered to have acid generating potential. The acid production potential of materials with an ACA/APP ratio between 4 and 1 was considered uncertain and confirmation testing may be conducted to determine the acid generating potential of the material.

Laboratory Column Testing

Prior to the field program, the effect of placing the waste rock into the flooded open pit was determined by completing a laboratory column test with the waste rock and the open pit water. The results of the program were used to help predict any changes in water quality that would occur during dewatering of the open pit and waste rock placement and to predict potential long term impacts.

Forty-five liters of pit water and a 2 kilogram sample of the "F" zone waste rock were collected and transported to the Lakefield Research Limited environmental facilities for testing. The simulation was performed using a plastic column, 10 centimeters in diameter and 1.5 meters in height. A volume of water, 8,260 mls, was placed in the column. This water was sampled and analyzed before the placement of rock into the column. The water samples were analyzed for ICP metal scan (total and dissolved), pH, acidity, alkalinity, conductivity, total suspended solids and sulphate. The waste rock from the "F" zone, was crushed to minus 6 mesh (Tyler) and placed in the column at 2% of the volume of water, which was similar to the ratio of rock to water that would occur in the field. The total volume of rock placed into the column was 165.22 cubic centimeters. The water in the column was sampled and tested 24 hours after the placement of the rock in the column for the aforementioned parameters. These results were used to help predict any changes in water quality that would occur during dewatering of the pit and waste rock placement.

FIELD PROGRAM

An in-pit disposal program was developed for the waste rock using the results of the laboratory test program. The following were considered during the design of the Simple Underwater Disposal (SUD) program.

- the flooded open pit contained no known surface discharge areas;
- the pit water quality was acceptable for discharging to the environment because there was no degradation of the pit water from the pit wall rock and ground water;
- the waste rock volume to be placed in the open pit was 2% of the open pit capacity;
- the acid generating waste rock would be placed at the deepest and central location of the open pit which would reduce the oxidation potential of the sulfides;
- elimination of long term liability of acid generating waste rock was required, and;
- the disposal method used must be cost effective.

The data from the waste rock sampling program and the topographic surveying that was completed in August of 1994 was used to determine the approximate quantities of waste rock that could be extracted and placed in the open pit.

The in-pit disposal program was discussed with the Manitoba Ministry of Environment prior to the start of the program. The Ministry of Environment verbally approved the concept of dewatering a percentage of the open pit after reviewing the water quality data. A work permit from the Manitoba Ministry of Natural Resources was obtained for mine reclamation.

The in-pit disposal program commenced on May 7, 1995 and was finished on May 20, 1995, for a duration of 14 days. During the in-pit disposal program, it was necessary to dewater the open pit to 1.5 meters below the existing pit water elevation. Approximately 30,000 m^3 (7.9 million U.S. gallons) of pit water was discharged. The pit water was discharged to the creek adjacent to the open pit. This exposed the existing pit ramp which was used for the placement of the waste rock into the bottom of the flooded open pit.

Inert waste rock was placed over the existing pit ramp to ensure the safety of the trucks when transporting waste rock to the open pit. A berm was constructed at the water edge of the ramp to ensure the safety of the trucks while on the ramp.

The acid generating waste rock from the "F" zone was extracted, transported and place into the flooded open pit. The waste rock was excavated to the clay horizon. The clay was recontoured at the areas of extraction. The potentially acid generating waste rock along the road was extracted to a depth between 0.5 meters and 1.0 meters, depending on the quality of the waste rock.

Approximately 7,700 tonnes of waste rock material from the Pumphouse Road area was extracted to the clay horizon, transported and placed into the flooded open pit. The primary area of focus was the previous pumphouse location along the shore of the river and the access road which was constructed of acid generating waste rock.

After all of the waste rock had been placed into the open pit, the upper 0.5 metres of the ramp was excavated and placed into the open pit. This was done to ensure that all the waste rock that spilled onto the ramp was placed in the open pit. It appeared that the majority of the waste rock had been successfully placed into the deepest cut of the open pit. This was determined by measuring the depth of the disposal area at the open pit with a depth indicator.

Analytical testing conducted before and after the field program showed the water quality at the "F" Zone dramatically improved after the extraction of the acid generating waste rock. The water was sampled at the toe of the waste rock pile prior to the extraction process (Pre Extract) and 14 days after the extraction process of the waste rock (Post Extract).

COMPARISON OF BENCH AND FIELD RESULTS

The results of the laboratory column test and the analytical results conducted on samples collected during the field program showed that the column test was a good indicator of what occurred in the field. The column test and field results showed an iron concentration increase of 2 fold. The pH of the water in the column test remained constant and this was also observed in the field. The conductivity of the column test water decreased. This decrease was also reflected in the field results.

Some discrepancies were also noted between the field and laboratory results. The column test showed that the nickel concentrations would increase, however the field results showed that the nickel concentration remained stable. The analytical results of the column test results also showed that the Total Suspended Solids (TSS) concentration levels would increase, but the field results showed that the TSS were not detectable both before and after placement of the acid generating waste rock into the open pit. This may have been due to the increased settling time available in the field. It was anticipated at the beginning of the program that the increased dilution and settling time in the field would result in better water quality than in the laboratory. Therefore the laboratory was used to determine the worst case scenario which was not observed during the field program.

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RECLAMATION, TRANS CANADA HIGHWAY TWINNING, BANFF NATIONAL PARK

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INTRODUCTION

Parks Canada's primary objective is the protection and preservation of the natural environments. The Trans Canada Highway is Canada's primary east-west transportation route from St. John's Newfoundland to Victoria, British Columbia, with the twinning changing a two-lane highway built in the early sixties to a median separated highway with dual east and westbound lanes. The SADT of 13,500+- vehicles has resulted in extensive platooning and a number of serious accidents, thus necessitating the need to continue with the twinning of an 18.2 km section from the Sunshine to Castle Interchange. Banff National Park has been recognized as a World Heritage Site, putting additional emphasis on environmental protection. Spiking of some trees withing the proposed Right of Way to hopefully stop the twinning has received wide media coverage.

PHASE I & II TWINNING

Work on Phase I started in 1980 and Phase II in 1984 with the twinning of the Trans Canada Highway from the Banff National Park East Gate to the Sunshine Interchange completed and providing relevant information for the current Phase IIIA Twinning Works. Phase I & II cover a length of 26.5 km, medians are wide with remaining forest cover where possible by the terrain,--- with narrow, Concrete Barrier Medians in areas of difficult terrain. Eight feet high Wildlife exclusion fencing has reduced wildlife mortality to 5% of the previous levels. Ten Wildlife Underpasses were constructed consisting of Bridge Structures with a 15 m wide top-span, 4m high vertical clearance and a level 4-5m wide passage area at the bottom. A Multi-Plate-Culvert with a 4m height and 7m width also was constructed and proved successful. These underpasses are used by bears (even though some black bears have been observed of climbing the fence), they receive high use by ungulates, Rocky Mountain Sheep and small mammals. On the other hand the page wire fencing does allow the penetration of Coyote, who seek out the grasslands within the fenced Right-of-Way leading to a high mortality rate. Therefore the decision has been taken to use variable mesh fencing with closer wire spacing at the bottom for the Phase III Twinning.

The driving experience is pleasant, with the one way traffic flow allowing the drivers more time to enjoy the mountain scenery. Special care was taken to realign Chinamen's Creek providing pools and riffles and generally improving fisheries for the Brown and Brook Trout. Two

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weeks ago I personally observed some monsterfish. The required borrow materials for Phase II were extracted from Healy Creek Pit, creating a much improved Ungulate Habitat in the process. This no longer can be classified as the typical borrow area, this is a pleasant landscape of interconnected extraction areas with gentle, rolling cut slopes and protective tree cover within 100 metres from any foraging areas. What started out as a grassy mono-culture has turned into a bio-diverse landscape with flowering native legumes and forbs, invading tree and shrub seedlings, and shallow ponds with emergent sedge and willow vegetation.

PHASE IIIA TWINNING

With this experience under out belts we set out to design and construct the 18.2 km of twinning for the Trans Canada Highway from the Sunshine to Castle Mountain Interchange within a montane/sub-alpine environment. The montane valley bottoms present the most productive environment within Banff National Park, which is especially important as winter wildlife range. Unfortunately, the valley bottoms have also seen the highest level of man-made infrastructure. The existing highway alignment is along the lower north facing slopes of the Bow Valley, with the slopes on the south and the Bow River on the north side, thus limiting alignment changes for the twinned highway. In order to minimize any adverse environmental impacts the following measures have or will be taken:

* The chosen alignment is at the toe of the north facing slopes to avoid more productive valley-bottom lands.

* More than 1km of narrow median using Concrete Jersey barriers will be constructed to reduce environmental impact.

* Rather than using the valley bottom or Mannix Pit as a source for the required borrow material, all material will be borrowed from the km 39 sidehill cut borrow area in a less sensitive environment.

* Even though the earlier proposed highway alignment showed some encroachments on open river waters, the alignment in the final design avoids any infringement upon river waters.

* Impact on sensitive wetlands has been minimized by avoiding them and through run-off control.

* The bridge over Red Earth Creek is being constructed while none of the fish are spawning, with the new culvert Crossing over Wolverine Creek completed while no waters flowed in this intermittent mountain stream.

* Culverts for any potentially fish-bearing streams have been set to facilitate fish passage.

* The decision has been made to continue with the 8 feet high wild life exclusion fencing along the entire right-of-way using a variable mesh pagewire fencing. The final fence location will be chosen to maximize wildlife habitat, a visually/aesthetically acceptable alignment and maintenance access/ repair. This wildlife fence will reduce wildlife mortality due to vehicle collisions by at least 95 %.

* 30% of the total twinning budget will be spend on environmental mitigation, two major wildlife overpasses will be constructed at a cost of 2 million dollars each, two major 4m high, 7m wide & 30 m long clear span underpasses will be constructed, numerous other wildlife underpasses with a minimum size of 1.0m to facilitate wildlife movement will also be constructed.

* Two Picnic Areas have been closed, two trailheads will be retained as well as the Castle Mountain viewpoint for a reduced environmental impact.

* Retaining walls will be constructed using naturally coloured concrete to minimize visual and sidehill impacts, with 0.9: 1 rock retaining slopes proposed to avoid impact on open water.

* All topsoil and fine grained subsoils will be salvaged, with all disturbed areas covered with a 10 cm of topsoil prior to seeding.

* Slopes will be established generally to a maximum gradient of 2:1 to facilitate a permanent vegetation cover. Slopes will also be rounded and modulated to achieve a natural look.

* Rather than burning, ---all roots, stumps, brush and tree trunks less than 10 cm in diameter will be chipped for composting and later reclamation use.

* merchantable timber has been sold with the credit applied towards this project providing for improved mitigations.

* All disturbed areas will be seeded to a native grass mixture of Northern Wheatgrass, Streambank Wheatgrass, Slender Wheatgrass, Fringed Brome, Tufted Hairgrass, Fowl Bluegrass, Rocky Mountain Fescue, Junegrass, Alpine Bluegrass with 5% non-native Perennial Ryegrass added as short-lived nursecrop. The proposed seeding will also use Biosol an organic fertilizer to activate soil bacterial action and provide slow, non-leaching nutrient release, with Copolymers, Woodfibre Mulch, and Tackifier to prevent surface erosion.

*Extensive plantings using landscaped sized native trees and shrubs will be used for the Wildlife Over and Underpasses. Reforestation plantings using locally collected tree seed are planned to soften the exposed forest edges.

* An Environmental Subcommittee and an Environmental Surveillance Officer assigned full-time to this project will ensure acceptable reclamation and mitigation procedures.

The twinning works for Phase III A are in progress. When complete, I expect happy wildlife and happy people,---if some people will be unhappy, it will not be for lack of reclamation effort.

RAILWAY RECLAMATION: ISSUES AND OPPORTUNITIES[1]

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HISTORY AND LEGISLATION

As of August 15, 1978 the *Land Surface Conservation and Reclamation Act* required, among other things, the reclamation of railways covered under the *Railway Act of Canada*. Railways abandoned before that date were not subject to the legislation.

On September 1, 1993, Alberta's *Environmental Protection and Enhancement Act* came into effect. The Act, and the *Conservation and Reclamation Regulation*, again required that these lines be reclaimed following abandonment and added the requirement that operators obtain a reclamation certificate. In neither case did the Acts refer to the construction or operations phases of railways since the lines are for the most part constructed and operated under federal legislation.

In 1994, in response to requests for information from the railway industry with respect to the criteria for railway reclamation, a joint government/industry/public Steering Committee was struck to discuss issues. The Steering Committee assigned the task of developing reclamation criteria to a Working Group composed of members from Alberta Environmental Protection, Alberta Agriculture, Food and Rural Development, three railway companies (CN, CP, CWR), the Farmers' Advocate, and the Alberta Association of Municipalities, Districts and Counties..

The first task of the Working Group was to establish a clear understanding of which railway lines were affected by the legislation. The Working Group recommended changes to the definition of "railway" in the Act and regulations to include railways not covered under the *Railway Act of Canada* (e.g., lines operating under provincial jurisdiction such as Central Western Railways).

The Working Group also recommended clarifying that railway lines abandoned before August 15, 1978 were not subject to the Act, and that railway lines abandoned between August 15, 1978 and September 1, 1993 would require reclamation but be exempt from the requirement for a reclamation certificate. The latter exemption recognizes that no detailed reclamation criteria were in place between the two dates. However, with no reclamation certificate, the operator of the railway line retains liability for reclamation issues relative to the requirements outlined in the criteria. These changes will be formally implemented when the *Conservation and Reclamation Regulation* is amended in September, 1996..

When the Regulation is amended, an Information Letter entitled *Reclamation Criteria for Abandoned Railways* will be released. The Information Letter, and the associated reclamation certificate application form represents the results of the Working Group.

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[1] Presented at the 21st Annual Meeting, Canadian Land Reclamation Association, Calgary, Alberta, September 18-20, 1996.

[1] Présenté a la 21ème réunion annuelle de l'Association Canadienne de Réhabilitation des Sites Dégradés, Calgary, Alberta, September 18-20, 1996.

RECLAMATION OPPORTUNITIES

Like most things in real life, one person's opportunity is another's issue. The following are two examples of this:

In many cases, railway lines bisect land parcels resulting in fragmentation of farming practices. Reclaiming railways to allow landowners to rejoin their land parcels would seem to be a natural choice. However, this would require that each landowner buy the reclaimed land adjacent to their own land. The railways have indicated a preference to sell the line in large blocks rather than have the added expense of dealing with many purchasers.

Reclaiming railways to be multi-use trails, forming part of the proposed cross-Canada trail system, seems to be a natural opportunity - no new land is required, the trail bed is already prepared, rivers and streams are already crossed, and the lines go between places that logically fit the trail concept. Indeed, in the United States the Rails to Trails Conservancy actively promotes the conversion of abandoned railways to this use resulting in approximately 5,000 km of trails (see their internet home page at http://www.rail-trail.org/fredwert/). There are over 300 km of rail trails in Ontario. However, the idea of uncontrolled access to land adjacent to their farms and neighbourhoods has many rural Albertans concerned about damage to their property. Concerns include vandalism, litter, fences being cut, livestock being spooked, loud vehicle traffic and parties. There is also the issue of who will maintain the trail in suitable shape, especially structures and controlling weeds.

RECLAMATION ISSUES

The Working Group and the Steering Committee agreed that reclamation of railway lines was important and that criteria outlining the expectations of government would help operators. The criteria would also help adjacent landowners understand what to expect when the lines were reclaimed. Some of the issues that arose during the discussions are outlined below:

Landuse

Farmers expect to be able to crop the reclaimed railway line just as they expect to be able to crop a reclaimed wellsite. Managers of public land want to ensure that land use is not restricted and that the vegetation on the line is suitable in native prairie areas. Legislation generally supports the return of the original land use, which necessitates return of original contour and watercourses.

The Working Group recognized several impediments to meeting these goals:

- many railways were designed as permanent features so no topsoil was saved;
- railway beds were constructed from material adjacent to the bed itself or imported from pits - removing the bed would require significant disturbance to the adjacent environment and considerable cost;
- railways have been in place so long that new water systems (e.g., sloughs, stream beds) have developed adjacent to them;
- much of the original disturbance may have revegetated naturally; and
- some older abandoned railways, overgrown with shrubs and trees, have been shown to provide good wildlife habitat and travel corridors in areas where such habitat is often limited.

Taking all these factors into consideration, the Working Group recommended criteria that require:

- identification and remediation of all contamination to meet provincial standards;
- removal of infrastructure (rails, ties, poles, pipes, etc.);
- removal of the ballast (unless the railbed is to be used as a road);
- recontouring where unstable or erosive conditions are found or created through removal of bridges or culverts; and
- revegetation (unless the railbed is to be used as a road or trail).

The original contours are not expected to be re-established, because of cost and the potential removal of valuable wildlife habitat, although operators are encouraged to work with adjacent landowners to ensure that safe access across the line is possible.

Liability for Structures

The main point of contention was who is responsible for structures (e.g., bridges and culverts) that remain in place. Safety is obviously the key issue for bridges. Significant concerns exist for culverts because of the potential to become plugged or to collapse, resulting in upstream damage to property and the environment. Public land managers were adamant that lines abandoned on public land would have to have all structures removed. Landowner representatives were very concerned about the potential transfer of liability to purchasers and adjacent property owners.

Interpretations by various lawyers of the legislation and the laws surrounding conditions of sale and purchase did not clarify issues. The criteria were drawn up to read that bridges and culverts were to be removed unless specified to the contrary in the purchase and sale agreement. In the latter case, the purchaser then becomes responsible for the structures. The results of future sales, reclamation and possible litigation will determine the need for future revisions to the criteria.

Responsibility for Remediation and Reclamation

The Act is quite clear in specifying that the operator of the railway is responsible for remediation of contaminants and reclamation of the line. The Act is also clear that until a reclamation certificate is received, the operator remains liable for reclamation issues (i.e., those requirements outlined in the criteria).

Some recent purchase and sale agreements include provisions transferring any remediation and reclamation liability, not specified, onto the purchaser. The clauses suggest that, as the purchaser has made his own assessments of the line and is purchasing the line in an "as is" condition, the purchaser has accepted the liabilities for the property. Again legal advice from various parties produced mixed messages with respect to whether the legislation or the signed purchase agreement has priority. The Department still believes that the Act says the operator is responsible.

Summary

The Working Group and the Steering Committee have developed a workable set of reclamation criteria that will ensure the return of a safe, stable, non-erosive landscape. The criteria try to take into account the wishes of potential purchasers who may want some of the facilities such as culverts or ballast or bridges left in place while at the same time protecting the interests of those who do not want these facilities.

The criteria are not set in stone. To date only one request for a reclamation certificate has been received since the criteria have been developed. A small section of line in Edmonton was given a reclamation certificate in the fall of 1995. As we develop more experience with the criteria (see paper by Mark Polet for an example) we may find that they require changes to become more effective and efficient. The Steering Committee will meet periodically to review the criteria and determine the need for modifications.

A number of legal issues arose during the development of the criteria. Unfortunately, only experience gained over time will tell which legal interpretations are the correct ones.

The biggest test of the criteria will come when lines become abandoned and are put up for sale. The buyers of the lines will judge the success of the industry's reclamation efforts with their cheque books.

EXPERIENCES IN RECLAIMING RAILWAYS UNDER ALBERTA'S NEW RECLAMATION GUIDELINES

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INTRODUCTION

Central Western Railway (CWR) was obligated to abandon 64 km of railway in the Alberta Plains region east of Consort. This line was built in 1914. This was the first line to be abandoned under the new guidelines proposed by Alberta Environmental Protection. This paper will present the experiences in planning the reclamation, as at time of publication work was still ongoing. This paper will focus on the unique features of reclamation in comparison to other linear developments, and discuss the application of Alberta Environmental Protection's Draft Reclamation Criteria for Abandoned Railways. In effect, since the reclamation is underway, this paper is but an interim report, and further experiences will be presented at the conference.

DISCUSSION

Features of Reclamation of Railways

Railways share the same reclamation challenges as other linear developments as they often include:

- access challenges after the track is pulled,
- crossing several different habitats,
- water body crossings, and
- slope stability issues.

Therefore similar tools can be used. The preparation of reclamation plans is made easier by the presence of accurate surveys and the fact that the right-of-way (ROW) stands out clearly on air photos. Employees often have long tenure and are a valuable source of guidance and information.

Railways also pose some unique challenges in reclamation. Rail transport can not tolerate steep grades or curves so land forms and features are more severely bisected than by other linear developments. Cuts and fills are more pronounced, and drainages are more severely affected and sometimes permanently altered.

In addition, the high activity of railway building occurred in the late 19th Century and early 20th Century. Top soil salvage was in must cases not recognized, and often the equipment was not available for phased stripping. However that same lack of equipment and horsepower meant that less ROW was disturbed.

Many railways were also built before water conservation acts and regulations were enforced. Many were built under Federal Statute which either took precedence in law, or at the very least removed them from provincial or local jurisdiction. The consequent fact is that drainages were often altered or stopped altogether.

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Another outstanding issue is environmental contamination concerns. It is extremely difficult to assess potential contamination as activity on individual lines varies so greatly. One could face almost pristine conditions, or alternatively an old Division Point could still be contaminated from activities during the steam era.

However, some advantages to the reclamation specialist come with the additional challenges of reclaiming railways. Firstly, vegetation is often well established. In many cases, railways were built before the surrounding land was cultivated and provide an ecological refugia particularly for native plant species. It appears they may also provide a travel lanes for wildlife, but the evidence is circumstantial.

Secondly, the track itself often has a high salvage value. A prudent railway company or reclamation specialist can ensure that the surface and subsurface structures will be removed by the Salvager at the time the rails are recovered. The rails' salvage value generally pays for the extra effort in removing other infrastructure. This is made more important since once the rails are removed, access is very much restricted.

Lastly, the land is often valuable as either a row required by another entity, an ecological refugia, or for the extension of existing activities on neighbouring parcels of land.

Application of Reclamation Criteria for Abandoned Railways

During the planning of reclamation, representatives of Alberta Environmental Protection joined CWR representatives and the reclamation specialist to tour the line in detail. Structures requiring removal were noted, as were areas where excessive ballast required removal.

The most difficult decisions to make surrounded the questions of removal of culverts. Such removal often requires the need for extensive regrading and disturbance of stable, revegetated, slopes; however their retention raises the concern of an eventual collapse of the culvert, and the leaving behind of often pronounced artificial cuts and fills. The results of those discussions are still ongoing; and their resolution will be discussed further during the presentation of this paper.

The guidelines produced by Alberta Environmental Protection accommodates the potential land use of the ROW, contaminant variability, and the technical issues of shallow grades and pronounced cuts and fills. In short it provides the operator and regulator sufficient adaptability to accommodate the unique features of railways.

PIPELINE ABANDONMENT: A DISCUSSION PAPER ON TECHNICAL AND ENVIRONMENTAL ISSUES[1]

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ABSTRACT

Approximately 540,000 km of operating pipelines currently exist in Canada; roughly 50 percent of which are located in Alberta. An increasing number of pipeline systems have reached the end of their useful life and are being abandoned in place. No guidelines presently exist in Canada that deal with pipeline abandonment in terms of the appropriate methods of abandoning lines, the methods for assessing abandonment costs, and the funding for orphaned abandoned lines. Concern over the responsibility for abandoned pipelines from a safety, environmental, financial and legal perspective has become a growing issue for the Regulatory Authorities and the Oil and Gas Industry. Together they have formed a joint steering committee and subcommittees to examine the issues of pipeline abandonment and produce a discussion paper.

An abandonment plan is a framework to direct a project such that public safety and the minimization of any environmental impacts are highlighted. To develop a responsible abandonment plan, an operator must consider issues covering environmental, technical, legal and financial concerns. Most issues are not unique to the abandonment phase of the facility life cycle, but may include an altered scope, varied timeline and additional stakeholders in comparison to pipeline installation and operation. The scope of issues addressed includes subsidence, contamination, water crossing, erosion, land management, restoration, utility and pipeline crossings, creation of water conduits, associated apparatus, and the cost of abandonment.

A specific project will likely include a combination of pipe removal and abandonment-in-place over the length of the pipeline. A key characteristic affecting the operator choice of abandonment options and the subsequent abandonment plan is the land use. Both options, removal and abandonment-in-place, have associated levels of surface disturbance required. Abandonment-in-place does not eliminate the need for disturbance and field activity, nor does removal have to encompass the same level of disturbance or activity as installation.

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[1] Présenté a la 21ème réunion annuelle de l'Association Canadienne de Réhabilitation des Sites Dégradés, Calgary, Alberta, September 18-20, 1996.

LEGAL PERSPECTIVE ON LAND RECLAMATION[1]

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ABSTRACT

The *Environmental Protection and Enhancement Act*, S.A. 1992, c.E-13.3 (EPEA) places a duty on operators to reclaim land. Understanding the definition of operator, which has been clarified in the latest amendment of EPEA, is the first step in understanding the duty to reclaim.

The second step in understanding this duty is the definition of "specified land", found largely in the regulations (*Conservation and Reclamation Regulation* AR 115/93). Together, the concepts of operator and specified land combine to identify who has the duty to reclaim.

The next step in understanding this duty is to understand that it starts at the beginning of an activity. In some circumstances, the operator will require an approval (*Activities Designation Regulation* AR 110/93) and a reclamation certificate. EPEA also now provides for a registration or notification in some circumstances (*Activities Designation Regulation*). In other situations, the operator will only require a reclamation certificate.

The reclamation certificate, issued following the inquiry procedure described in the *Conservation and Reclamation Regulation*, is the final step in understanding the duty to reclaim. The effect of the reclamation certificate is best understood by examining the ability of inspectors to issue Environmental Protection Orders (on- and off-site), Emergency Environmental Protection Orders, Environmental Protection Orders after a reclamation certificate has been issued, and finally, the appeal process to the Environmental Appeal Board.

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LIABILITY FOR RECLAMATION: WHO IS AN "OPERATOR"?

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INTRODUCTION

Part 5 of Alberta's *Environmental Protection and Enhancement Act* ("AEPEA") and the Conservation and Reclamation Regulation thereunder, clearly set out the objective of reclamation of specified industrial land and that is "to return the specified land to an equivalent land capability". The responsibility, and liability, for such reclamation of specified land rests with the "operator".

This presentation will focus on the liability of the "operator" for reclamation and how the definition of "operator" under AEPEA has been interpreted in a recent decision of the Alberta Environmental Appeal Board ("EAB").

DEFINITION OF "OPERATOR"

The duty to reclaim falls on the "operator" under AEPEA. Section 122 of AEPEA provides that an operator must reclaim specified land and that the reclamation must be carried out in accordance with (a) the terms and conditions of any applicable approval (b) the terms and conditions of any environmental protection order regarding reclamation (c) the directions of an inspector or the Director, and (d) AEPEA.

"Operator" is broadly defined in Section 119(b) of AEPEA.

> "119(b) "[o]perator" means
> (i) an approval holder who carries on or has carried on an activity on or in respect of specified land pursuant to an approval,
> (ii) any person who carries on or has carried on an activity on or in respect of specified land other than pursuant to an approval,
> (iii) a successor, assignee, executor, administrator, receiver, receiver-manager or trustee of a person referred to in sub-clause (i) or (ii), and
> (iv) a person who acts as principal or agent of a person referred to in sub-clause (i), (ii) or (iii);".

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Specified land is defined in the regulations under AEPEA to include land that is being or has been used in connection with wells, larger scale coal mines, pipelines, transmission lines, oil sands sites, heavy oil sites, sand and gravel pits, quarries and peat operations.

Reclamation of specified land is not considered complete until an inspector examines the area and issues a reclamation certificate pursuant to Section 123 of AEPEA. If at the time of an inspection for a reclamation certificate, deficiencies are found, the inspector may issue an environmental protection order to an operator directing the performance of any work necessary in order to reclaim the specified land. The environmental protection order may also extend to off-site damage.

All liability for remedial obligations under Part 5 of AEPEA rests with the "operator". How the definition of "operator" under AEPEA is interpreted is an extremely important issue, both with respect to initial responsibility and ultimate liability for reclamation.

JUDICIAL INTERPRETATION

A May, 1995 decision of the Alberta Environmental Appeal Board, *Sarg Oils Ltd. v. Alberta* [1995] A.E.A.B.D. No. 4, Appeal No. 94-011 addressed the issue of the definition of "operator" as found in Section 119(b) of AEPEA and the issue of liability of company directors for activities of their companies.

Sixteen well sites in the Camrose area were inspected and deemed to be improperly reclaimed. Sarg Oils Ltd. ("Sarg") was the registered licensee of the 16 abandoned well sites and Sergius Mankow ("Mankow") was the president and shareholder of Sarg.

In September, 1994, 16 environmental protection orders were issued to Sarg and Mankow requiring reclamation of all the sites. The orders were appealed and the issue in the appeal was whether Sarg was an "operator". Sarg had transferred its interest in the wells to a third party but was still registered as the licensee with the Alberta Energy and Utilities Board ("AEUB"). A second issue on the appeal was whether the company's director was liable as an operator.

The arguments on the appeal were that:

1. Mankow was not an "operator";
2. any activities carried on at the site were carried on by predecessors or successors to Sarg;
3. the only reason Sarg appeared as the registered licensee was because the AEUB did not transfer the registration of the well license from Sarg to the third party in 1988; and
4. Sarg had transferred its entire interest in the well sites to a third party and it had no legal standing to undertake any activities on the sites.

Notwithstanding that the definition of operator includes anyone who has carried on an activity on the site, the Director's position has been that he will look to the party recorded on the AEUB records as licensee, since the wells do not require an approval under AEPEA. The Director's position has been that the licensee can then seek contribution from other parties if appropriate. This has also been the position held by the AEUB.

The EAB held that the Director acted reasonably in relying on the AEUB registry to determine who was the operator with respect to the 16 well sites. The Board also held that the Director was correct in determining that Mankow was a person against whom an environmental protection order could be issued. As Mankow was a shareholder and president of

Sarg, he was unquestionably an agent of the operator.

Sarg and Mankow made an application to the Court of Queen's Bench for judicial review of the EAB's decision. The application was heard on March 29th, 1996 and the Court set aside the EAB's decision and ordered that the EAB consider the matter once again. The Court's ruling was based on failure of the EAB to hold an oral hearing or give Sarg and Mankow an opportunity to make further written representations. The Court did not review the EAB's conclusion. The EAB is scheduled to consider this matter again in November, 1996.

There is a second appeal by Gammon Resources before the EAB concerning the definition of "operator". It is scheduled to be heard in October, 1996.

SUMMARY

The decision in *Sarg* is important in shedding some light on how broadly the definition of "operator" will be interpreted and ultimately who will be liable for reclamation of specified land. The decision:

1. confirms the Director's position in using the AEUB registry to determine who is an operator of well sites which are not required to have approvals under AEPEA;

2. confirms the potential liability of directors and officers of a company as agents and directing minds of a company; and

3. illustrates how broadly the provisions of AEPEA will be interpreted and the widening scope of potentially responsible persons for reclamation.

COURSIER RESERVOIR: THE PLANNING AND COSTS ASSOCIATED WITH THE RECONSTRUCTION AND REVEGETATION OF A SUBALPINE LAKE.

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Coursier Lake is a 200 hectare(ha) reservoir situated at 1270 metres(m) above sea level approximately 45 kilometres southwest of the City of Revelstoke. The dam was built in 1963 by the City of Revelstoke and purchased by B.C. Hydro in 1972. As part of a regular dam safety investigation in 1993, sink holes were discovered in the upstream face of the earthfill dam. The abandonment of the dam was one of several alternatives studied as part of an assessment to address the problem. In order to prepare a cost estimate for reclaiming the reservoir after abandonment, the following environmental issues were assessed: a review of the pre-disturbance habitat using historic air photos, a hydrological study of outlet channel reconstruction, a reclamation plan for the shoreline and original stream channel and a revegetation plan.

Pre-disturbance Habitat and Existing Conditions

Historic photographs and air photos indicate a small 45 ha lake occupied a U-shaped valley before the dam was built. The forested valley slopes extended to the lake shore and the original stream channel meandered through an area of flat wetlands and marshes. Air photo interpretation was used to measure the surface areas of the pre-dam vegetation conditions. Of the 210 ha of land area disturbed by the construction of the earthen dam and flooding of the lake bed, approximately 45 ha was the original lake basin, 87 ha was forested and 70 ha was wetlands.

The flooded shoreline was established at an elevation of 1283 m, 17 m above the pre-dam lake shoreline of 1266 m. The flooded area was cleared of trees and the original soils are now buried under a thin layer of silt and clay which has settled out from the reservoir. The original drainage pattern along the valley bottom appears well-preserved, although somewhat obscured by siltation, as does the original lake shoreline. The limits of the forested areas are clearly defined by the remnant tree stumps.

Breach of the Dam and Reconstruction of the Outlet Channel

Breaching of the dam would involve the removal of approximately 85,000 cubic metres of fill to reduce the elevation of the dam from 1285 m to the original lake level of 1266 m. The

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breach would be a 20 m deep notch in the existing earthfill dam. The outlet channel would be 20 m wide increasing to a width of 120 m wide at the top of the notch with terraced slopes of 2.5:1. The main purpose of this design was to create a stable slope that would withstand flood conditions and that would support revegetation of the slopes. The excess fill would be used to reclaim the spillway, intake and tailrace channel structures.

The reconstructed outlet channel must provide a final grade that would allow fish passage and withstand a 1 in 10,000 year flood. Based on these criteria a channel almost 50 m in length with a maximum grade of 2.5% was designed. A main feature of this plan was the construction of 6 large boulder riffles which reduce the steep gradient and water velocities to allow fish access. The total cost for this stage of the lake reconstruction would be approximately $770,000.

Reclamation of Shoreline and Original Tributary

The flooded shoreline at 1283 m has developed a small scarp that would require protection from slope runoff to reduce sedimentation into the lake. Revegetation of this scarp would control erosion in most of the areas with the exception of large gullies formed by intermittent streams along the shoreline. Approximately 20 large gullies would need to be reinforced with large riprap blankets to accommodate the high flows during the spring freshet.

The original tributary is relatively unaltered by decades of inundation and would require only minor stabilization. This would involve the construction of steepened boulder rapids at the entrance to the original lake. Rather than remove any silts accumulated in the original tributary it is anticipated that within 2-3 years the finer materials would be flushed out naturally. The estimated cost to complete this stage of lake reconstruction would be $100,000.

Revegetation Plan

The revegetation plan for the 87 ha of forested and 70 ha of wetland vegetation would be in two phases. Phase one would entail heli-seeding the entire shoreline and dam surface with an annual plant species, such as fall rye, to reduce erosion and act as a nurse crop for natural vegetation. Initial greenhouse experiments with shoreline sediments indicate a viable seedbank is still present and may be able to re-establish a large percentage of the original plant species.

Phase two would include the planting of wetland and forested plant species. Depending on the success of the natural vegetation, some of the 70 ha of wetland area may require additional plantings including willow, sedge and grass species. Based on previous studies possible species to use could include:

- *Carex sitchensis* (Sitka Sedge)
- *C. aperta* (Columbia Sedge)
- *C. aquatilus* (Water Sedge)
- *C. languinosa* (Woolly Sedge)
- *Deschampsia caespitosa* (Tufted Hairgrass)

- *Salix scouleriana* (Mountain Willow)
- *S. glauca* (Greyleaf Willow)
- *S. bebianna* (Beaked Willow)
- *Populas balsamifera ssp. Trichocarpa* (Black Cottonwood)

AIM Ecological Consultants have successfully cultivated these species using cuttings and seeds grown in a greenhouse and then hand-planted into disturbed areas for other B.C. Hydro projects. The approximate cost to grow and transplant these species is $1.25 - 2.00 per plant. Planting spacing for sedges, grasses and rushes is in general 2 plants per square metre and for willows 0.5 plants per square metre. This amounts to $12,500 per hectare to revegetate with sedges and $3,125 per hectare for willows. To reflect the original habitat balance these plantings would cover a maximum area of 55 hectares of sedges and 25 hectares of willow - this would total a cost of $750,000. This cost would likely be less if the native vegetation was even somewhat successful in re-establishing from the sediment seedbank.

The 87 hectares of forest habitat would be replanted to a density of 1200 stems per hectare with Ministry of Forests recommended species such as *Picea engelmannii* (Engelmann spruce) and *Abies lasiocarpa* (Subalpine fir). This would cost approximately $100,000. It is expected that this stand density would produce a self sustaining forest in an excess of 700 stems per ha within 9 - 15 years after planting.

Summary

The entire process of abandoning the dam would include these three main reclamation activities as well as an initial environmental approval review and a monitoring phase prior to returning the land to the Crown. It was estimated that the approval process would take two years, the reconstruction and revegetation work two years and the regrowth and monitoring phase 15-20 years for a total project cost of $1.5 million.

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SPRAY LAKES RECLAMATION PROJECT

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INTRODUCTION

The Spray Lakes Reservoir, located 16 km south of Canmore, is in the subalpine ecoregion of Kananaskis Country. Developed in 1951 after the construction of Three Sisters and Canyon Dams, the Reservoir provides water for three power generating stations. The lake reaches its peak elevation (full supply) in late July to early August. Drawdown is approximately 12.5 metres with its lowest level occurring during the winter months. The lake is widely used by fishing, boating and camping enthusiasts.

The Three Sisters Dam at the lake's north end was not originally designed for the probable maximum flood (pmf) risk. This risk combined with known seepage beneath the dam led to a decision in 1987 to permanently lower the full supply level (fsl) of the lake from 1701.7 metres above sea level (masl) to 1697.6 masl so the pmf could be maintained. The dam was also upgraded to control seepage. As a result of the lower lake level, 208 hectares (ha) of shoreline was exposed offering little to no wildlife benefit and limited recreation potential.

In 1991, TransAlta Utilities developed a reclamation plan for 128 ha of shoreline and an earthen spillway adjacent to Canyon Dam. Input from Alberta Forest Service, Trout Unlimited, Kananaskis Country as well as public and interest groups was incorporated into the plan. The objectives of the project were to sustain the integrity of the lake by enhancing the aesthetic value for recreational users, as well as to provide forage and habitat to wildlife by establishing a palatable, self-sustaining vegetative cover. Work would take place from 1992 to 1995.

METHODS AND PROCEDURES

The shoreline was subdivided into high, moderate or low priority areas based on public accessibility, visibility and usage. Further subdivision of the shoreline was done based on slope, substrate conditions and the presence or absence of tree stumps. In this manner specific reclamation prescriptions could be developed and applied to each site category. On the high and moderate priority areas, exposed tree stumps not removed in the original construction of the Reservoir were removed and either burned, buried, or salvaged for artificial reef construction by Trout Unlimited. Most of these shoreline areas were scarified by dragging the teeth on the bucket of a tracked excavator. Scarification improved the seedbed by loosening the fine soil material which underlay the cobbly material. This process would enhance seed germination by aerating the soil as well as improve moisture infiltration.

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On less cobbly areas, diamond harrows were used to scarify the soil before and after seeding. On some sites, seed was track-packed using a tracked excavator. This technique improved the seed/soil contact as well as created soil microsites for moisture to be retained.

All areas were broadcast-seeded by electric spreaders mounted on a six wheel drive all-terrain type of vehicle. On steep slopes and riparian areas, hand seeders were used. The seed mix, applied at a rate of 28 kg/ha, was composed of creeping red fescue, Canada bluegrass, wheatgrasses, hard fescue, alfalfa and white clover with an approximate percent by weight composition at 7, 5, 12, 11, 28, and 23%, respectively. The species were selected based on their adaptation to alkaline soils, drought tolerance, persistence in a stand and rooting characteristics, as well as palatability to wildlife. Alfalfa and white clover were used because of the plant's characteristic nitrogen-fixing ability in the soil which would, in turn, enhance the self-maintenance of the vegetative stand. Fall rye was also included in the mix at 14% by weight. Used as a cover crop, this annual grass helped to protect the soil from further erosion while providing a rapid cover for the slower-establishing perennial grasses and legumes. Following seeding, fertilizer was applied at a rate of 30-50-100-20 kg/ha of nitrogen, phosphorus as P_2O_5, potassium as K_2O and sulfur, respectively.

Other reclamation work included the extension of a boat launch at the Driftwood Day Picnic area to allow easier access to the lake. Also in this area, due to intensive use by the public, silt from a plateau located below full supply was hauled onto the cobbly shore and respread providing a more favorable seedbed which could withstand heavy use.

At the Sparrowhawk Day Picnic area, a steep cliff which had eroded as a result of wave action at the lake's original fsl was recontoured to reduce the hazard to public users of the area.

At Spurling Creek, stream channels flowing into the reservoir which were between the former fsl and the new fsl had no defined channel and erosion had occurred. Therefore, a channel was contoured and its bank lined with riprap to prevent further erosion and silt from entering the lake.

At various locations, log jams resulting from the initial clearing of the reservoir had developed along the forested edge of the lake, posing a forest fire threat as they dried out. To eliminate the hazard, the piles were pulled away, burned and buried below the full supply level. The areas were then seeded and fertilized.

A high priority area was identified at a campground near the Three Sisters Dam which, unlike other shoreline areas, was relatively flat and therefore caused a larger shoreline area to be exposed at the new fsl. To break up the openness of the landscape, trees would be planted along with the grass/legume mix. In the spring of 1992, 7800 willow and poplar cuttings were collected from stock near the dam and raised in a greenhouse over the summer. In the fall, the trees were planted by volunteers from Scouts Canada.

In the spring of 1993, reclamation work continued on an additional 14 ha of shoreline and a 13 ha earthen spillway at Canyon Dam. These areas were scarified, seeded and fertilized as in the previous year. Straw mulch was applied to the entire spillway area. Mulch aided in protecting the seedbed from erosion as well as protecting the soil from moisture loss and temperature extremes. Fertilizer was reapplied to approximately 60 ha of the shoreline which was seeded in 1992.

In 1994 and 1995, reclamation activities included refertilizing areas seeded in 1992 and 1993 and monitoring of the vegetative establishment on the shoreline. Areal application of fertilizer was performed by helicopter in the spillway while shoreline areas were fertilized by hand or mechanically .

RESULTS AND DISCUSSION

In total, 131 ha of shoreline and a 13.35 ha spillway have been revegetated with grasses and legumes. Of these areas, approximately 90 ha was scarified, and/or had tree stumps removed prior to seeding. Approximately 40 ha was seeded and fertilized only. The remainder of the shoreline, approximately 77 ha, was not revegetated mainly due to limited access. These areas will be allowed to re-establish naturally from the forested edge.

In general, all areas outlined in the reclamation plan are successfully revegetated. Areas which were recontoured and riprapped are stable and non-eroding. Establishment success was most significant in areas which had been scarified then seeded and trackpacked. The areas where silt was respread or straw mulched showed good plant establishment within the first growing season.

Areas which were seeded and fertilized without scarification or harrowing operations were less established in the first growing season, however, these sites were better established in their second and third years of growth.

Overall, the changes made to the shoreline and public use areas have improved their usage by both wildlife and the public. In the future, TransAlta will continue to monitor the Spray Lakes Reservoir to ensure the reclaimed vegetation is self-sustaining and that the aesthetic and biological improvements will be enhanced for years to come.

THE PINE COULEE PROJECT
LINKING RECLAMATION PLANNING TO IMPACT ASSESSMENT*

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PROJECT DESCRIPTION

The Pine Coulee Project is a $42 million off-stream water storage reservoir in the Willow Creek basin in southwestern Alberta. It will provide water for irrigation and for improved instream flows for fish and water quality in lower Willow Creek. The project will consist of a diversion weir with a 40 ha headpond, a 3.5 km canal and a 600 ha reservoir. The reservoir will be created by a 31 m high dam across the nearby Pine Creek valley. The project also entails the construction of a causeway and bridge and the relocation of several roads. Each of these project elements will have associated borrow areas, equipment and materials storage areas, field offices and haul roads. Construction is scheduled to start in the fall of 1996 and will be completed over three years.

Once operating, during high flow periods the diversion weir will direct a portion of the flow of Willow Creek to the reservoir via the canal. This water will then be released down Pine Creek and back to Willow Creek to meet downstream demands. The diversion and release of water are subject to instream flow needs criteria that recognize requirements for water quality, fish habitat, recreation and riparian vegetation.

PROJECT ENVIRONMENT

Pine Coulee is just east of the Porcupine Hills in the foothills Fescue Grass Ecoregion. It is a glacial meltwater channel running north-south across a landscape that slopes gently to the east. Most of the surrounding land is cropped. Much of the coulee bottom has been broken and seeded to pasture but most has reverted to alkali grass and foxtail barley. The valley side slopes are generally undisturbed and support native grassland communities, predominantly blue grama - prairie sagewort and blue grama - prairie sagewort - june grass. Moister sites support buckbrush - rose stands.

The canal alignment cuts through an area of native blue grama - prairie sagewort - june grass. The area that will be flooded by the diversion weir headpond contains grassland, cropland and riparian poplar (Populus balsamifera).

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* Presented at the 21st Annual Meeting, Canadian Land Reclamation Association, Calgary, Alberta, September 18-20, 1996.

The project area is located in the transition from the Dark Brown to the Black Soil Zones, but most of the soils are Dark Brown Chernozems. Due to the complex topography of the area there is a wide range in soil characteristics. Although there are locations with well developed and fertile soils, there is much rough broken land, and large areas of recent alluvial or colluvial deposits with little horizon development. Much of the bottomland in Pine Coulee is saline.

ENVIRONMENTAL IMPACT ASSESSMENT

This project was the first in Canada to undergo a joint federal-provincial review. After extensive technical study, public consultation and environmental impact assessment, the project was the subject of a Natural Resources Conservation Board/Environmental Assessment and Review Process Joint Review Panel hearing. The main environmental losses identified by Spencer Environmental Management Services Ltd. (1993) were:

1. native grassland that would be inundated by flooding, eliminated by canal construction and damaged by other construction activities;
2. riparian poplar flooded by the headpond; and
3. northern pike spawning habitat, some of which would be made unavailable by the barrier created by the weir and some which would be lost due to reduced spring flooding.

The Environmental Impact Assessment (EIA) embraced the principle of no net loss in valued environmental resources. This principle was generally accepted during the hearing and is reflected in NRCB/EARP Joint Review Panel (1995). This required quantifying losses and proposing a replacement strategy. Reclamation for the project was included in the strategy.

MITIGATION AND RECLAMATION

Grassland

The EIA estimated that 576 ha of grassland would be lost to flooding and construction. The possibility of returning cropland to grassland to compensate for losses was discussed at the hearing. The project environmental team maintained that this approach was neither economically nor ecologically feasible. The Federation of Alberta Naturalists' representative at the hearing supported the team's view. The approach proposed was to minimize losses by:

1. controlling construction activities and educating workers;
2. locating borrow and disposal sites within the reservoir or on previously disturbed sites; and
3. reclaiming construction disturbances using native vegetation.

Next, the team proposed to replace lost grasslands, not with equal quantity, but improved quality. The EIA outlines several methods to gain control of grasslands and manage them to achieve greater species diversity and productivity. A combination of these methods will likely be used. An accounting method based on standard range condition assessment techniques supplemented by six habitat suitability indices is proposed to determine program adequacy.

For the reclamation of site disturbances in areas to be returned to grassland, the following techniques have been specified.

1. Compacted sites will be scarified.
2. A base of topsoil stripped from the disturbed area will be spread on the scarified site.
3. This will be topped with a layer of material stripped from a native grass stand within the reservoir and immediately respread.
4. This will be overseeded with a cover crop.
5. On slopes flatter than three to one straw will be spread and crimped in for erosion protection. On steeper slopes a hydromulch will be used.

Riparian Poplars

Approximately 11 ha of riparian poplar will be flooded by the diversion weir head pond and other construction activities. Again, the first priority is to minimize losses through construction planning and controls. Losses will be replaced by:

1. using riparian poplar in reclaiming suitable granular borrow pits;
2. restoring and managing other nearby stands; and
3. if necessary, planting and managing new stands adjacent to the headpond.

Pike Spawning Habitat

Northern pike is the predominant sport fish in lower Willow Creek. Pike spawn in flooded vegetation adjacent to the stream channel during spring floods. The weir will create a barrier to the upstream movement of pike denying them access to upstream spawning areas. As well, spring flooding downstream will be somewhat lowered reducing the area of spawning habitat. Total reduction in pike spawning habitat is estimated at 5 to 10 ha. Replacement of this habitat is one of the conditions of NRCB approval for the project.

Plans are to reclaim the major granular borrow pit downstream of the dam to create the replacement habitat. This will involve grading to create large areas of shallow water that will be planted with emergent and flood tolerant vegetation. Water will be routed through this marsh both from the dam outlet channel and from Willow Creek to maintain appropriate water depths and temperatures.

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DESIGN AND CONSTRUCTION MANAGEMENT ASPECTS OF CONSTRUCTED WETLANDS

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INTRODUCTION

Integration of constructed wetlands within land reclamation schemes afford opportunities to manage runoff, provide habitat and protect surface water quality. Constructed wetlands concepts can be applied to deal with poorly drained areas and can enhance the habitat and water quality value of post-reclamation ponds and lakes.

CONSTRUCTED WETLANDS DEFINITIONS

In considering application of wetland ecosystems for water quality enhancement, a very broad definition of "wetland" is useful.

> *"Wetland is defined as land having the water table at, near or above the land surface or which is saturated for a long enough period to promote wetland or aquatic processes as indicated by hydric soils, hydrophitic vegetation and various kinds of biological activity which are adapted to the wet environment."* (Tarnocai, 1979)

This definition includes a wide range of systems and land forms including ponds, marshes, sloughs, muskeg, wet meadows and floodable forests which provides an extensive palette for water management, site rehabilitation and landscape design.

Wetlands can also be distinguished by the degree of human intervention and four distinctions are commonly used (US SCS, 1992):

Natural wetlands:	no human alteration
Restored wetlands:	reconstructed on former wetland sites
Created wetlands:	constructed on sites where no wetlands existed primarily to compensate for natural wetlands lost to development
Constructed wetlands:	constructed with the intent of managing water quality

Natural wetlands are not typically used for wastewater treatment. Constructed wetlands are designed with flow paths, water depths, water distribution and vegetation compatible with the influent stream in a way which results in the desired effluent quality, aesthetics and habitat features.

CONSTRUCTED WETLANDS APPLICATIONS

Constructed wetlands have been used for a variety of water management purposes:

Municipal Wastewater Treatment: Secondary - tertiary treatment of domestic or municipal wastewater. Constructed wetlands are used to enhance removal of organic material, suspended solids and nutrients.

Agricultural Wastewater and Runoff Treatment: Constructed wetlands and wetland concepts (e.g. floodable buffer strips) are used to treat effluents from intensive livestock operations and runoff from cultivated and pasture lands.

Mine Drainage: Remove suspended solids and metals, as well as adjust pH of contaminated runoff and drainage from mine sites. If systems receive runoff from eroding sites, inlet ponds can be provided to reduce sediment loads on the marsh cells.

Industrial Wastewater Treatment: Provide secondary, tertiary and/or polishing treatment for industrial effluents and site runoff for pulp mill effluents, refinery wastewater, food processing plant discharges and runoff from industrial sites.

Leachate Treatment: Remove oxygen demand, suspended solids, metals, organics and nitrogenous compounds from municipal and industrial landfill leachates and surface runoff.

Stormwater Management: Removal of suspended solids, bacteria, organic matter and nutrients from urban runoff. Stormwater wetlands are also employed as runoff detention facilities to reduce downstream flooding risks.

MULTIPLE BENEFIT DESIGN OPPORTUNITIES WITH CONSTRUCTED WETLANDS

Among water treatment technologies, constructed wetlands concepts provide an opportunity to design with multiple values in mind incorporating engineering function, wildlife habitat, naturalized vegetation and pleasing aesthetics into a single project. In many cases the combination of these values into design can lower costs, enhance land values and increase public acceptance of related facilities.

Functional Purpose: The engineering function is usually a primary purpose for developing a facility. Such functions include contaminant removal from domestic wastewater, sediment removal from runoff and detention to control peak stormwater flows.

Aesthetic Value: Naturalized wetland sites can be aesthetically pleasing and can enhance the experience of surrounding land uses, in fact stormwater wetlands have been shown to increase the value of surrounding properties. By utilizing floodable forests and wetlands, natural appearing buffers can be established surrounding gravel operations, landfills and industrial sites. The concept transforms a regulatory necessity such as stormwater containment into an amenity which enhances the public perception of the proposed site use.

Ecological Enhancement: Constructed wetlands can provide a wide range of habitat which compensate for loss of natural areas to urban and industrial development. Designed with marsh, open water pond and upland buffer vegetation zones, these wetlands provide a diversity of micro-habitats for a wide range of wildlife. Stormwater wetlands and associated overland flow channels can form the basis of linear urban park systems which can provide important wildlife corridors in developed areas. Wetland modifications such as aquatic benches and shore fringe can improve the habitat value of lagoons and stormwater lakes by providing cover, food and nesting habitat.

Recreational Uses: Pathways and wildlife viewing points (bird watching) integrated into constructed wetland projects can provide increasingly sought after nature-centered recreation. The inclusion of naturalized vegetation (wet meadows, marsh areas, floodable forests) attracts animal life and presents a diverse, seasonally changing experience for recreational users.

Developer Benefit: Naturally vegetated systems of distributed stormwater wetland detention sites with interconnecting overland drainage channels would not only greatly enhance stormwater quality but also could reduce costs for piped stormwater systems. Park-like stormwater facilities have become perceived as amenities by consumers increasing the value of lots abutting the sites. Creation of naturalized open spaces with lower maintenance costs can appeal to municipal agencies increasing the chances for land use designations favorable to the developer.

CASE STUDIES

Calgary Constructed Wetland Pilot Project
- Objectives: Evaluate water treatment capability of stormwater wetlands in Calgary climate.
- Design Features: Alternating pond - marsh zones and vegetation test areas.
- Ancillary Benefits: Future development as an urban park - wetland interpretive site.

Winnipeg West End Pollution Control Center Lagoon Decommissioning
- Objectives: Retain obsolete lagoons for waterfowl habitat.
- Design Features: Enhancement of lagoons with aquatic bench marsh zones.
- Ancillary Benefits: Incremental effluent treatment and lower reclamation costs.

Bow Ridge Stormwater Wetland
- Objectives: Address anticipated public and municipal objections to development.
- Design Features: Reconstruction of riparian wetland area with pond and marsh zones.
- Ancillary Benefits: Will provide stormwater water quality enhancement and park area.

Calgary Zoo Northern Forest Wetland
- Objectives: Reduce potential contaminants in runoff and drainage from zoo exhibits.
- Design Features: Floodable forest detention/treatment zone, wetland habitat exhibits
- Ancillary Benefits: Wetland interpretive displays, regulatory/public acceptance.

Hobbema Correctional Facility Integrated Water Reuse Wetland
- Objectives: Provide for integrated water use and domestic wastewater reuse.
- Design Features: Packaged treatment unit, wetland polishing and storage ponds.
- Ancillary Benefits: Landscape amenities and acceptance of on-site effluent irrigation.

Edgemont Stormwater Wetland
- Objectives: Provide stormwater detention.
- Design Features: Sediment forebay, passive subsurface wet meadow irrigation.
- Ancillary Benefits: Park area, water quality improvement and amenity land value.

Nowicki Farm Feedlot Runoff Treatment Wetland
- Objectives: Reduce contaminants in runoff from feedlot.
- Design Features: Inlet pond and multiple marsh zones.
- Ancillary Benefits: Improved land drainage and reduced cattle health risks

Gregg River Coal Mine Aquatic Habitat Enhancement Wetlands
- Objectives: Reclamation of coal mine including end-cut lake.
- Design Features: Marshes to intercept inflow and end cut lake littoral wetland zones.
- Ancillary Benefits: Addition of nutrients, vegetation and detritus to enhance fishery.

CONCLUSIONS

Constructed wetlands using concepts such as marshes, ponds and floodable forests have a role in land reclamation, as well as in mitigating the impacts of development. With consideration of potential multiple values, wetlands can provide water quality improvement, hydrological control, habitat enhancement and human amenity. Early applications of constructed wetlands in Western Canada indicate the techniques are feasible and cost effective.

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NATURAL REVEGETATION OF AN ALBERTA PEATLAND AFTER HORTICULTURAL PEAT EXTRACTION

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INTRODUCTION

Natural revegetation of peatlands after horticultural peat extraction, which hasn't been previously documented in Alberta, is described herein in relation to feasibility as a reclamation option. A peatland of several hundred hectares, located 100 km west of Edmonton, Alberta, was harvested and then abandoned in several stages between 1970 and 1980. No reclamation was initiated and the drainage network was left partially functional. The cutover bog is characterized by a variety of site types with differences in peat thickness, water table regime, peat botanical composition, peat chemistry and topography, and it has since been colonized by differing vegetation associations.

Colonization of abandoned, cutover bogs has been described elsewhere (Elling and Knight 1984; Famous et al., 1991; Jonsson-Ninniss and Middleton 1991; Salonen and Setala 1992), and research is underway at the University of Alberta and at Laval University to establish *Sphagnum* and other native peatland species. Knowledge of critical site environmental parameters will help land managers anticipate the direction of revegetation and evaluate feasibility of natural revegetation as a reclamation option. A two year study was initiated in 1994 to investigate the ecosite characteristics of five site types approximately 14 years after abandonment.

METHODOLOGY

Preliminary ecosite mapping and soil and water chemistry data for this project was available from a broader reclamation project involving development of a protocol for soil inventory of cutover peatlands (Turchenek et al. 1993). Five site types were selected, subjectively based on observable differences in vegetation composition. Four replicate plots of each site type were established.

Each 25 m^2 plot was centered on a capped, slotted, 5 cm I.D. groundwater monitoring tube. Water table levels were measured bi-monthly from May to October in 1994 and 1995. Vegetation species were identified and percent cover for each species was estimated. Soils were sampled with a MacCauley corer at 1-10 cm and 10-25 cm intervals from 10 sample points within each plot and then composited for analysis. Soils were analyzed for pH, weak acid extractable Ca, Mg, K, and P, and for KCl extractable NO_3 and NH_4. The degree of decomposition was estimated using the von Post index and rubbed fibre measurements, bulk density was determined by volumetric sampling, and botanical composition was estimated visually.

RESULTS

Vegetation

An adjacent undisturbed site was characterized by typical bog species (*Picea mariana/Ledum groenlandicum/ Sphagnum spp.* site type) . The site is dominated by hummock-forming *Sphagnum spp.* and *Ledum groenlandicum* accompanied by several lichen species and an open overstory of stunted *Picea mariana*. Few other non-*Sphagnum* mosses or sedges were present and brown mosses were absent.

The five study site types were designated as: i) barren peat, ii) *Betula/Eriophorum*, iii) *Eriophorum*/moss, iv) *Betula/Ledum/Polytrichum*, and v) *Carex*/moss. A component of bare peat was present in all disturbed sites, ranging from a mean low of 2% in the *Carex*/moss site type to 100% in the barren peat site type. Species numbers ranged from 9 to 23 in the replicate plots while the undisturbed site had a similarly low number of 20 species. However, the disturbed sites differed considerably from the undisturbed site in species composition. For example, *Picea mariana* and *Smilacina trifolia* had not yet become established on any disturbed sites and the variety of

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lichens was less on any given plot. *Sphagnum* spp. mosses were neither widespread nor present in the same percentage as in the undisturbed site.

Sphagnum spp. and brown mosses were nearly absent from the relatively dry *Betula/Eriophorum* and *Betula/ Ledum/Polytrichum* sites. The relatively wetter *Carex*/moss and *Eriophorum*/moss site types were colonized by a variety of brown (e.g., *Polytrichum strictum* and *Aulacomnium palustre*) and *Sphagnum* species but lacked lichens. Species common to most of the disturbed site types included *Betula neoalaskana*, *Salix maccaliana*, *Calamagrostis canadensis*, *Eriophorum vaginatum* and *Polytrichum strictum*.

In general, a wider variety of trees, shrubs, herbs, graminoids and moss species have become established in the cutover peatland sites as compared to the undisturbed peatland. The presence of a variety of brown mosses in the *Carex*/moss and *Eriophorum*/moss site types suggests a nutrient regime that differs from the original bog peatland.

Peat Chemistry and Composition

pH levels were typical of native bog and poor fen systems, although the barren peat and *Betula/Eriophorum* pH values were significantly lower than in the *Carex*/moss sites. Extractable nutrient levels in the peat soils at all sites were low and were comparable to low values reported previously (Turchenek et al 1993). The barren peat site type had the lowest levels of P, Ca, Mg and K, while the peat substrate in the *Carex*/moss site type had the highest levels of these nutrients. Contents of NO_3 and NH_4 were highest in the barren peat and the *Betula/ Eriophorum* peat soils.

The degree of decomposition and the botanical composition of the peat materials at the five sites were similar. Nutrient contents between some of the site types were significantly different. The most common occurrences of differences in nutrient contents occurred between the barren peat site type and one or more of the other types.

Water Table Levels

There was considerable variation within and between some sites at any given time. Heavy precipitation during July 1994 and August 1995 produced significant short-term rises in water level at all site types. The barren peat site type had the greatest variability, ranging from -126 to -11 cm with a mean of -60 cm. The *Betula/Ledum/ Polytrichum* site type was less variable and had a mean of -36 cm for two replicates and -60 cm for the other two. The wettest site types, *Carex*/moss and *Eriophorum*/moss, had mean water levels within 10 cm of the surface and had relatively low temporal variability. The *Carex*/moss site type was flooded for an extended period in 1994.

DISCUSSION

The barren peat, *Betula/Eriophorum* and two of the *Betula/Ledum/Polytrichum* replicates had water table levels that averaged -40 cm or less. This depth is considered the minimum for survival of *Sphagnum* mosses. The barren peat surface can become very dry and subject to wind erosion with excessively low water table levels. In contrast, the *Eriophorum*/moss site type had consistently high water levels, at or slightly above the peat surface, as well as the greatest *Sphagnum* moss component with hummock formation. The *Carex*/moss site type, being flooded for long periods with water depths up to 20 cm, was too wet for many of the species present in the other site types. The *Betula/Eriophorum* site type was very similar to the barren peat site type except for a higher mean water level of 40 cm. The two *Betula/Ledum/ Polytrichum* replicates, with a mean -36 cm water table level, had a dense *Polytrichum* cover in which *Sphagnum fuscum* was becoming established.

The five site types were similar in terms of composition and degree of humification of the peat. The peat substrates among the sites differed to some extent. The barren peat and two of the *Betula/Ledum/Polytrichum* site types were most similar with regard to water table levels, however, P, Ca, Mg and K were higher in the latter site type. Thus, substrate fertility appears to be a factor in the development of different site types. The relatively high NO_3 and NH_4 of the barren peat and *Betula/Eriophorum* site types was likely attributable to accumulation as a consequence of absence of vegetation that would normally utilize these nutrients. The dominance of *Eriophorum vaginatum* in the *Betula/Eriophorum* site type may be related to the relatively high NH_4 in the peat as this species has been shown to favour NH_4-N in its nitrogen uptake (Salonen and Setala 1992).

The slightly higher pH levels in the *Betula/Ledum/Polytrichum*, *Carex*/moss and *Eriophorum*/moss site types suggest that they are richer in nutrients than the barren peat and *Betula/Eriophorum* site types. The differences in nutrient contents, however, may be attributable to replenishment arising from higher water tables in some of the site types.

CONCLUSIONS

1. The rate of natural revegetation on cutover peatlands depends on the site conditions, in particular, the water table level. Adverse site conditions can prevent any revegetation for at least 15 years.
2. *Sphagnum* moss development appears to be limited to sites with a mean water table level higher than -40 cm and preferably within -20 cm.
3. Lichen, *Betula*, *Ledum* and *Picea* species were most prevalent in sites where the mean water table level was between -30 and -60 cm.
4. Dry, nutrient-poor sites are the slowest to revegetate. Mean water table levels of -60 cm result in a peat surface that is too dry for plant establishment. Reclamation assistance is required for such sites.
5. *Carex spp.* can become well established in less than 10 years and will tend to be dominant in areas subject to long term inundation.
6. The number of species that become established in a site type is similar to that of a typical bog; however, the species are different. Diversity in post-harvest site types leads to relatively high diversity in species composition.
7. It appears that the current stage of revegetation and sequence of colonization is similar to that noted by researchers in Eastern Canada. For example, bog species such as *Picea mariana* and *Smilacina trifolia* are very slow to return to a disturbed peatland.
8. The success of natural revegetation depends on the time horizon acceptable to the land manager. Five to ten years is likely required to colonize and stabilize most peatlands assuming site conditions are suitable. The return to the original bog species composition may require many decades.
9. Water table management is essential to ensure successful revegetation and to guide the direction of revegetation. Soil chemistry adjustment may be required for problem soils.

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COMPUTER MODELLING OF SOIL EROSION FROM RECLAIMED LAND[1]

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ABSTRACT

This paper describes a project in which a physically-based computer model was used to estimate soil losses on reclaimed land. The Water Erosion Prediction Project (WEPP) model was used to simulate long term soil erosion rates on reclaimed lands at Suncor Inc.'s oil sands mine at Fort McMurray, Alberta. WEPP predicts runoff and soil erosion for both rainfall and snowmelt events. It includes both sheet erosion and gully erosion. The WEPP model was calibrated using data collected from a series of full scale field rainfall-runoff-erosion simulations carried out at three sites representing three different reclamation conditions: mature reclamation; mature reclamation after a controlled burn simulating forest fire; and recent reclamation. All of the sites were on steep (3H:1V) sand dyke slopes.

The 50 years of observed climatic data series at the project area were extended to a 1000 year period by stochastic means. This generated climatic series, together with calibrated model parameters and other input data, were then used to model long term soil erosion. Long term mean annual sediment yields from sheet erosion were estimated to be 0.004 mm on mature reclamation, 0.016 mm on recent reclamation and 0.008 mm on burned soil. The results demonstrate that the development of mature vegetation can significantly reduce soil erosion potential and that a forest fire can temporarily increase soil erosion rates.

Gully erosion was modelled for mature and recent conditions. Long term mean annual sediment yields from a typical gully catchment were estimated to be 0.071 mm on mature reclamation and 0.125 mm on recent reclamation. The model was used to estimate the influence of slope steepness, soils, vegetation, and catchment area on erosion rates. Growth rates for an extreme gully were also estimated using WEPP. The model indicates that a gully in the sand dyke would grow to an average size involving 650 m^3 of erosion over a period of 1000 years.

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RUNOFF AND SEDIMENT YIELD UNDER GRAZING IN FOOTHILLS FESCUE GRASSLANDS OF ALBERTA*

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BACKGROUND

Grazing has hydrologic impacts on Canadian foothills fescue grasslands through alteration of plant species composition, plant density, ground cover and litter (Johnston, 1961; Naeth et al., 1991a and 1991b). Livestock trample vegetation and may compact the soil (Naeth et al. 1990a), reduce infiltration (Naeth et al. 1990b), increase runoff (Johnston 1962) and alter soil water regime (Naeth et al. 1991c). Johnston (1962) found runoff and sediment yield from rainfall simulations increased with increased grazing intensity and reduced ground cover.

The objectives of this study were to quantify the effects of short duration and continuous (throughout the growing season) grazing systems on runoff and sediment yield from sloped areas of the foothills fescue grasslands of Alberta. There has been relatively little hydrologic research conducted on these or similar grasslands, particularly under snowmelt and natural precipitation conditions.

MATERIALS AND METHODS

The study site is located at the Agriculture Canada Stavely Range Substation, approximately 100 km northwest of Lethbridge, Alberta. Annual precipitation is approximately 550 mm with 40% occurring as snow (Strong and Leggat, 1981). The topography is generally hilly and slopes on the study site range from 18 to 37%. Soils are generally fertile and well drained. Black surface soil averages 8 to 10 cm in thickness with 5 cm on the uplands and 15 to 18 cm in gently rolling flats. Depth to the C horizon is approximately 60 cm. Dominant soils are Orthic Black Chernozems (Typic Cryoboroll) (Walker et al., 1991). *Festuca campestris* Rydb. (rough fescue) dominates the ungrazed and lightly grazed areas; *Danthonia parryi* Scribn. (Parry's oatgrass) dominates the heavily grazed areas and exposed sites with thin soils. There are a variety of subdominant grasses, forbs and shrubs. Lightly and heavily grazed fields were dominated by *Festuca campestris* and *Danthonia parryi*, respectively. Under very heavy grazing, *Festuca campestris* and litter were virtually eliminated. *Populus tremuloides* Michx. (trembling aspen) encroached upon lightly and moderately grazed grassland.

In 1988, research sites were established in the 40-year-old continuous grazing treatments and 4-year-old short duration grazing treatments. Treatments contrast between the historical grazing regime (continuous throughout the growing season) and short-duration, high intensity grazing. Continuous treatments were grazed from May through October; short-duration treatments were grazed for one week in mid-June. Heavy and very heavy stocking densities at 2.4 and 4.8 animal unit months (AUM) ha^{-1}, respectively, in both the short duration and continuous treatments, represent common grazing intensities for the area. The short duration treatments consisted of two 30 by 120 m grazed strips (heavy and very heavy grazing) and a 10 by 120 m control (ungrazed) each replicated three times, running downslope in a randomized split block design. The continuous treatments were located approximately 0.5 km from the short duration sites, running down the same slope but without a control. All treatments had an east facing aspect.

Runoff and sediment yield were monitored following snowmelt and after rainfall events using three 1-m^2 runoff frames per treatment (1 L of runoff corresponds to a water depth of 1 mm from the frames). The outlet end of the frames was trapezoidal in shape and was connected to a collection system consisting of a 20-L plastic pail located within a 64-L plastic pail buried in the ground. Upper-slope frames were installed in 1988 and mid-slope frames in 1989. At the time of runoff measurement, three subsamples of the runoff water, each 284 mL in size, were taken for sediment analyses. Samples were evaporated in a drying oven and the sediment weighed.

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* Presented at the 21st Annual Meeting, Canadian Land Reclamation Association, Calgary, Alberta, September 18-20, 1996.

Snow depth was measured with a meter stick at ten locations within each treatment/slope area near the runoff frames several times during the winter before snowmelt. The beginning of snowmelt was the time water started to run off from the frames. Snowmelt runoff volumes were generally determined several times during the snowmelt period and summed to give a total snowmelt value for each frame. Runoff was considered as accumulated runoff water from snowmelt and both as individual summer storm and accumulated summer runoff.

For each parameter, significant differences of the means were detected with Analysis of Variance techniques with design following the convention outlined in the SPSS-X User Manual (SPSS 1988) for split blocks. Significant effects were further evaluated using Student-Newman-Keul's (SNK) multiple comparison of means test at the 90% confidence limit (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Snow depth was greatest in the treatments with the highest amount of fallen and standing litter which effectively trapped snow. Average snowmelt runoff among treatments ranged from 3.3 to 105.7 L; this runoff was highest in 1991 and lowest in 1990. The ranking of snowmelt runoff by decreasing magnitude (1991, 1989 and 1990) parallels that of over-winter precipitation. Runoff was generally three to four times higher from mid-slope than from the upper-slope, likely due to a slightly steeper slope in the mid-slope position and more snow trapped there in the woody vegetation. There was a consistent trend across both grazing intensities of snowmelt volume with the very heavy treatments being less than those for the heavy treatments, except for the short duration treatments on the mid-slope in 1991.

Snowmelt runoff generally decreased with increasing grazing intensity from heavy to very heavy. The trend is likely due to higher litter and vegetation accumulations in the heavily grazed treatments which trapped more snow, resulting in increased runoff. Snowmelt runoff from the controls was generally similar to that from the short duration heavy treatment (average ratio of 1.01 across upper and mid slope positions and years), reflecting the trend in snow accumulation.

Sediment yields as a result of snowmelt were generally low: most were <4 g. Sediment yield was lowest in the short duration very heavy treatment, and was generally higher (average 312%) from the mid-slope position than the upper-slope position, a result of higher runoff in the former location. Sediment concentrations under snowmelt were generally similar across grazing treatments and dates, likely due to frozen soil conditions. Most concentrations were between 0.07 and 0.18 g L^{-1}. Concentrations for the upper-slope position were higher than those for the mid-slope position in all cases except two, by an average 61%.

Rainfall runoff was greatest from the short duration very heavy treatment in the mid-slope position in all three years and in one of four years in the upper-slope position. Runoff was generally lowest in the control. Runoff increased as grazing intensity increased (heavy to very heavy). On only five summer monitoring dates over four years were runoff volumes greater than 5 L: 18 August 1988, 19 June 1989, 2 and 16 August 1990, 8 October 1991. Runoff coefficients for rainstorm runoff were all below 0.11, indicating that only a small portion of rainfall results in runoff. These low runoff coefficients, even for heavily grazed areas, are likely due to the characteristic low intensity rainfall and to generally dry antecedent soil water conditions.

Total rainstorm sediment yields were generally highest for the continuous treatments and lowest for the control. There was a general trend to lower sediment yield in the upper slope position than in the mid-slope one. Of the 35 annual values reported, only 3 exceeded 10 g while 25 were less than 5 g. The majority of the total sediment yield occurred in August 1988 when 36.8 mm of rainfall fell on wet ground.

Sediment concentrations increased under grazing compared to the control and were 4 to 10 times higher under rainfall than snowmelt. Soil particle detachment occurs more easily under rainfall than snowmelt, resulting in the higher ratios under rainfall. Also detachment increases as protective vegetative cover is removed by grazing.

The highest sediment yield measured was 33.7 g; converted to a ha-basis, this gives an erosion rate of 0.337 t ha^{-1}; a very low rate. Because overland flow from above the frame was excluded, only runoff initiation processes were measured and thus sediment yields would be expected to be low. Thus, additional research is required to assess gully erosion, which occurs on a much broader scale, before definitive conclusions of the erosion susceptibility of these

rangelands can be drawn. Visual examination of these rangelands indicates the presence of gullies, probably due to the concentration of runoff flows from snowmelt and from the infrequent summer storms that cause runoff.

Annual runoff was dominated by snowmelt-induced runoff. On average, 70% of total annual runoff occurred as a result of snowmelt. Thus, snowmelt dominates annual runoff, regardless of slope position and grazing treatment, at this site. Snowmelt had previously been identified as the time of major runoff and erosion hazard for cultivated fields in the Peace River region of Alberta, with summer storms that caused significant erosion to be infrequent (Chanasyk and Woytowich, 1987).

CONCLUSIONS

The majority of annual runoff occurred during snowmelt. Snowmelt runoff decreased with increasing grazing intensity and was generally higher from the two heavy treatments and the control than from the very heavy treatments, due to the higher accumulated snow in the former treatments, in turn due to higher standing vegetation and litter there. Thus, any grazing regime that reduces vegetation markedly will also reduce snowmelt runoff in this area. Snowmelt sediment yields were generally low. Ratios of sediment yield to runoff volume under snowmelt were generally similar across grazing treatments and dates.

Few summer storms caused runoff, and runoff volumes from summer rainstorms were low. As grazing increased, so did rainstorm runoff coefficients and sediment yields. Rainstorm runoff coefficients increased over the control due to grazing, with intensity of grazing generally increasing the coefficients consistently only under short duration grazing and sometimes under continuous grazing. Rainstorm sediment concentrations increased under grazing compared to the control. Antecedent soil moisture conditions appear to play a significant role in determining whether summer runoff occurs.

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RUNOFF CURVE NUMBERS FOR TWO RECLAIMED WATERSHEDS IN CENTRAL ALBERTA*

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BACKGROUND

The Soil Conservation Service (SCS) runoff curve number method is one of the most widely used procedures for estimating the volume of storm runoff. Originally developed for application on ungaged agricultural watersheds, the procedure has been extended to urban catchments, used to assess changes to rainfall-runoff relationships after surface disturbances (Ritter, 1991) and is the procedure used by several continuous simulation models (e.g. EPIC, SWRRB, CREAMS and HYMO) for estimating storm runoff volumes (Williams et al., 1991). The attraction of the curve number method is that it is relatively simple to calculate and input parameters are readily available. Curve numbers are chosen based on soil infiltration characteristics and land use and management and then adjusted to reflect the antecedent soil moisture prior to the rainfall event. Curve numbers can be determined from measured rainfall-runoff relationships by rearranging the given SCS equations for both Q and S, solving for CN.

Although the curve number method is empirical, the strength of the method is in the large data set that was used to assign a curve number to a wide variety of soil type and cover for many of the soils in the United States. The procedure is being used to assess changes in surface runoff volumes after major soil disturbance even though very few studies have determined runoff curve numbers for the many different soils and soil covers on reclaimed watersheds. Schroeder (1987) used a rainfall simulator to determine and compare curve numbers for reclaimed grasslands to undisturbed grasslands. He found that for average antecedent conditions (AMC II), in reclaimed grasslands runoff curve numbers were higher than in undisturbed grasslands; for initially dry conditions (AMC I), there was no statistically significant difference. Ritter (1991) compared runoff curve numbers obtained from disturbed watersheds in central Pennsylvania to the curve numbers determined from SCS published handbooks and found that standard procedures underestimated curve numbers by as much as 50%. His recommendation was that for post-mine sandy loam or silt loam soils, the classification that reflects restricted infiltration be used.

The utility of the SCS curve number procedure to estimate runoff volume for a design storm from reclaimed watersheds is improved as curve numbers are determined for a range of post-mine soils and land covers. The goal of this study was to determine curve numbers for reclaimed watersheds based on measured rainfall and runoff on a micro and macro scale.

MATERIALS AND METHODS

Rainfall land runoff relationships were monitored at both the hillslope, using small 1-m^2 runoff frames, and watershed scale on two reclaimed fields for four years at the TransAlta Utilities Corporation Highvale Mine located approximately 80 km west of Edmonton, Alberta. The Sandy Subsoil watershed is 3.46 ha in area, seeded to a perennial forage, having north and south-facing slopes with a 15-17% slope gradient and a typical soil profile of 20- to 40-cm of loam to clay loam topsoil overlying a fairly homogeneous sandy loam texture subsoil. The West Watershed is 9.84 ha in area, also seeded to perennial forage, with north and south-facing slopes, with a slope gradient of 13% for approximately 10% of the area and a 5-6% slope gradient for the remainder of the area and a typical soil profile of approximately 20 cm of loam to clay loam topsoil overlying a 1.5-m subsoil layer of clay loam texture overlying clay textured spoil.

The number of rainfall events used to determine curve numbers for the hillslope frames varied from 5-39 on the Sandy Subsoil Watershed and 2-11 on the West Watershed. Three rainfall events were used on the Sandy Subsoil Watershed to determine curve numbers from the entire watershed and four were used for the West Watershed. Median curve numbers for the hillslopes were determined by combining curve numbers from all frames on the same aspect (6)

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within each watershed. Median curve numbers were used as the measurement parameter since much longer records are required for many of the other procedures (Hauser and Jones, 1991). Median curve numbers correspond to an average antecedent soil moisture condition (AMC II). An initial abstraction of 4.9 mm was determined from rainfall simulator studies on the Sandy Subsoil Watershed.

RESULTS AND DISCUSSION

The higher median curve numbers for the north-facing (CN 77) than the south-facing (CN 47) slope of the Sandy Subsoil Watershed reflects the differences in soil moisture between the two aspects during the growing season. Soil moisture was higher on the north-facing aspect than on the south-facing aspect throughout the entire growing season in all years. The median curve number for the south aspect may reflect a drier antecedent condition (AMC I) rather than AMC II.

The median curve number for the West watershed as a whole was 27, with a range of 8-65. The high curve number of 65 corresponded to a high intensity (peak 5-minute intensity of 130 mm h^{-1}) rainstorm with a return period of approximately 100 years. The median curve number reported from central Pennsylvania for similarly textured post-mine soil with similar vegetation was CN 80 (Ritter, 1991). Channeled transmission losses within our study watershed are high and watershed discharge only occurred during high intensity summer storms (Harms, 1996). The composite curve number for the watershed obtained from the north- and south-facing aspect results in an over-estimation of the curve number for the watershed. A transmission loss adjustment (Hailey and McGill, 1983) or factor, defined as the ratio of actual runoff to the runoff obtained using the curve number method (Madramootoo and Enright, 1991) has been proposed for watersheds where transmission losses are high.

The median curve number was higher on the north-facing slope of the West Watershed (CN 27) than on the south-facing slope (CN 65). Aspect is not as pronounced within this watershed and soil moisture was fairly uniform throughout the growing season. The bulk of the hillslope runoff during rainfall events came from only a few of the frames located on the south-facing aspect of this watershed and there was strong evidence of a perched watertable below these frames. Subsurface water would fill and slowly drain from aluminum access tubes installed for soil moisture readings for up to two weeks after a rainfall event.

The median curve number for the entire contributing area of the West Watershed was CN 41 with a high of 74 and a low of 23. The highest curve number was for the same high intensity storm that resulted in the highest curve number from the Sandy Subsoil Watershed. The median curve number is well below the SCS curve number of 81 for similarly textured soils. A composite curve number obtained from the hillslope frames would more closely approximate a watershed curve number than that from the Sandy Subsoil Watershed but it would still overestimate the actual curve number.

SUMMARY

It must be remembered that the curve number method was developed for a design rainfall event. For example, a Type II design storm for Montana is one where 71% of a 24-h rainfall event falls in a 6-h period and 45% of a 24-h storm falls in a 1-h period. Hjelmfelt (1991) reported that the curve number equation might best be used to transform a rainfall frequency distribution into a runoff frequency distribution, a procedure that required many years of runoff data. Using this approach yields generally good results if the percentage of rainfall that becomes runoff is high but poor when runoff is low (Hjelmfelt, 1980). Although the curve number procedure has compared favorably to other more complex methods of determining runoff from ungaged watersheds (Wilcox et al., 1990), median curve numbers determined for watersheds from only a few runoff events are likely to be gross approximations at best.

From our limited data set, median curve numbers for south- and north-facing hillslopes of similar post-mine soils and vegetation to that of the Sandy Subsoil Watershed can be assigned curve numbers of 47 and 77, respectively for AMC II. If curve numbers are used to design for rainstorms with a return period of greater than 25 years, the AMC III should be used for the hillslopes. Similarly, median curve numbers for reclaimed hillslopes of similar soils and vegetation to that of the West Watershed can be assigned CN 40 to 45 for AMC II and adjusted upwards for rainstorms with a return period of 25 years or longer.

Channel transmission losses are not accounted for in the curve number procedure but these losses have a strong influence on the validity of compositing curve numbers from different areas within a watershed to assign a final curve number for the watershed. When the runoff is directed into an ephemeral channel, a lower curve number than the area-weighted curve number determined from the individual hillslopes should be anticipated. For design purposes, curve numbers obtained from the longest return period rainfall event could be used (CN 65 for the Sandy Subsoil watershed and CN 74 for the West Watershed).

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VEGETATION CHARACTERISTICS, GRAZING DISTURBANCE AND SOIL EROSION*

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BACKGROUND

Annual domestic forages may provide temporary ground cover and pasture in reclamation situations where perennial domestic forages are not desired, cannot be established, or where a rapid ground cover is needed. Potential soil erosion is a concern in annual compared to perennial forages because of the requirement for yearly establishment. The row seeding of annual pasture may exacerbate rill erosion and the lack of litter buildup may leave the soil exposed to raindrop impact and surface flow (Tomanek, 1969; Wilcox, 1994). In comparison, perennial domestic pastures can protect against erosion by providing permanent cover (Meeuwig, 1970), forming sod and generating adequate litter (Naeth et al., 1991).

The objectives of this study were to quantify runoff and sediment during snowmelt and rainfall events and to measure differences in bare ground and litter on annual and perennial pasture at different grazing intensities.

MATERIALS AND METHODS

The study site was at the Agriculture and Agri-Food Canada Lacombe Research Station in the aspen parkland. Annual precipitation averages 447.5 mm. Soils at the study site are Orthic Black Chernozems of a sandy loam texture. Slopes average 1 to 3%.

Heavy, medium and light grazing intensity treatments were implemented on a rotational basis throughout the growing season. Grazing was initiated and ceased at different specific target forage heights for each grazing intensity. Four forage treatments with potentially differing abilities to control erosion and produce litter were used. Smooth bromegrass (*Bromus inermis* L.) and meadow bromegrass (*Bromus riparius* Rehm.) were the perennial treatments; triticale (*X Triticosecale* Whittmack) and a triticale/barley (*Hordeum vulgare* L.) mix were the annual treatments. The twelve resulting treatments were arranged in a randomized complete block design within four parallel blocks across an east-facing 3.8% slope.

A runoff frame assembly consisting of an above-ground 1-m^2 frame and an underground bucket collection system was installed in each treatment. Buckets within each frame assembly were checked after each rainfall event and during snowmelt. Runoff was subsampled for sediment content.

Litter was sampled in three randomly located 0.05 m^2 quadrats in each treatment before first grazing and after final grazing each year. Bare ground was measured in each treatment in five randomly located 0.10 m^2 quadrats during July of each year.

RESULTS AND DISCUSSION

Snowmelt was the dominant source of runoff. Few statistically significant treatment differences occurred for runoff and no consistent trends were noted other than snowmelt runoff in 1996 was greater than snowmelt runoff in 1995. All values were very low. Sediment yields were low and similar for snowmelt and rainfall. Few statistically significant treatment differences were measured and no consistent trends were noted other than snowmelt sediment

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yield in 1996 was consistently greater than in 1995. The high infiltration capacity and well-aggregated nature of the study site soils are reflected in these results.

Litter levels generally increased with decreased grazing intensity. Differences in litter with grazing intensity were more apparent in smooth bromegrass and meadow bromegrass treatments than in the annual treatments. Litter accumulated with time in these perennial treatments, however, this accumulation was considerably reduced at heavy grazing intensity.

Bare ground was higher under annuals than perennials in both years of the study and generally decreased with decreasing grazing intensity, especially in perennial treatments. Inter-row spaces in annuals greatly increased bare ground in this forage type, while the creeping habit of the perennial species tended to lose gaps in the canopy and provide more complete soil cover.

CONCLUSIONS

Snowmelt dominated annual runoff while sediment yield was similar for snowmelt and rainfall events. Runoff and sediment values were low. Bare ground was greater under annual than perennial forage treatments. Litter tended to decrease with increasing grazing intensity. Grazing intensity is a key factor in controlling erosion, especially erosion from growing season runoff. The soils at this site have a high infiltration capacity and are not as severely impacted by compaction as other more erosion prone soils might be.

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RENEWING THE ECOLOGICAL INTEGRITY OF DISTURBED NATIVE PRAIRIE[1]

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"In one human lifetime, the prairies have passed from wilderness to become the most altered habitat in this country and one of the most disturbed, ecologically simplified and over-exploited regions in the world." - Adrian Forsyth.

In Alberta, native prairie once covered vast areas of the province, from the U.S. border, north to Edmonton and beyond. Place names in the Peace River region, like Grande Prairie and High Prairie recall the native grassland that used to dominate the area. With the arrival of the railroad in Alberta in 1883, the prairie in Alberta was forever altered. By 1915, 2.7 million acres were converted to agricultural use. It is estimated that 20% of the mixed grass prairie found in southern Alberta (Morgan et al. 1995) and less than 1% of similar prairie in the Peace River region remain today. An estimated 20% of the foothills fescue prairie is intact, but in the flatter central area of the province, less than 5% of the northern fescue prairie (Wallis 1987) can be found.

The Public Lands Branch of Alberta Agriculture, Food and Rural Development manages some three million acres (1.2 million hectares) of native prairie owned by the government of Alberta. This land is managed for multiple uses, including grazing, wildlife habitat, watershed conservation, recreation, and industrial/commercial activities. Conserving the ecological integrity of native prairie ensures that multiple use benefits can be delivered now and in the future. Modern day threats to native prairie include fragmentation into increasingly smaller areas by cultivation and industrial development, over-grazing, and introduction and expansion of exotic (non-native) plants.

The remaining native prairie and its inherent biodiversity (variety of life) is being recognized for the benefits it provides. Some of these include soil formation and stability, nutrient cycling, natural control of pests, and amelioration of climate. (West, 1993). Recent field studies demonstrate that loss of plant species can threaten the ability of natural ecosystems to function and to be sustained in the long term (Frank and McNaughton 1991; Tilman et al. 1996). For example, a grassland with more plant species is more resistant to, and recovers more fully from, a major drought (Tilman and Downing 1994). The mixed grass prairie of southern Alberta supports a surprising total of 560 species of plants on various site types (Moss and Packer 1983) and an average of 50 different species of grasses and wildflowers in a quarter section (Wallis 1996).

Because of increasing public concern about industrial disturbance on native prairie and the difficulty of restoring disturbed prairie to its original condition, Public Lands has, along with other agencies, encouraged a minimal disturbance approach to industrial development. A publication entitled: "Petroleum Activity on Native Prairie: Guidelines for Surface Disturbances" (ERCB 1992) was developed jointly by five government agencies. An update of these guidelines will be published by the Alberta Energy and Utilities Board in 1996 .

Where possible, Public Lands requests companies to avoid smaller remnants of prairie, particularly the endangered fescue type. Vegetation inventories may be requested to determine what areas are particularly sensitive or where special techniques must be employed. Opportunities to reroute pipelines into less pristine areas or through cultivated fields should be explored. Oil and gas wells can sometimes be situated off sensitive prairie

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areas and directional drilling used to reach target zones. Where multiple wells occur, pad drilling is employed to help reduce disturbance from access and pipelining (the "spider web" syndrome). Pipelines can be run along access roads where feasible and common access can be used.

Public Lands is encouraged by the initiative that some companies have shown in pre-planning and in the innovative measures that have been implemented to reduce disturbance. Clay pads for drilling have been laid down over prairie vegetation on sandy sites during the winter and successfully removed. The vegetation has recovered within the following growing season, new growth emerging from undisturbed roots. "Minimum disturbance" wellsite drilling has reduced the area of conventional topsoil stripping, reducing disturbance to prairie vegetation in many areas.

Conventional pipelining has moved toward narrower zones of disturbance, and specialized equipment like the "Prairie Protector" (Nova Corp.), a flexible blade attachment for grader blades, has helped to reduce the risk of scalping native sod. "No strip" techniques have been used in pipelining in an attempt to reduce the disturbed area of prairie. This involves trench excavation with no topsoil salvage from the trench line. Excavated topsoil is placed on top of undisturbed prairie sod. A three year research study by Adams et al. (In press) compared "no strip" to conventional topsoil stripping for small diameter pipeline. It concluded that proper soil handling during construction is vitally important to the success of either technique. On the sandy and solonetzic site, substantial disturbance occurred with both soil handling methods. On the loamy site, more disturbance resulted with the topsoil stripping approach. Research is being proposed for a pipeline with a larger diameter to further compare the two pipeline construction techniques.

The current goal for reclamation of native prairie is to restore sound ecological function and eventually restore the original range of variability in biological structure and diversity. It is recognized that the latter may take decades or more to be realized. Our job as reclamationists is to learn how to correctly set the stage so that natural processes can complete the job. There may be multiple developmental pathways by which the goal can be reached. The prairie ecosystem is much more complicated than it first appears. The roles of various plants, particularly wildflowers and micro-organisms, are poorly understood. Some plants, e.g. the club moss that holds much of the prairie together at ground level, have never been successfully propagated, to our knowledge. Prairie vegetation has been around for a very long time; in fact, one naturalist has likened the prairie to an old growth forest. It is important to view the system as a whole and start to understand the links and interactions between physical, chemical and biological components.

Past revegetation practices have not always accomplished the goal of re-establishing biological structure or diversity. Public Lands field staff have noted that old disturbances (pre-1940) more closely resemble surrounding native prairie than areas seeded to crested wheatgrass from 1940-1990. In recent years, the shortcomings of this species have been realized. Although crested wheat-grass allows rapid revegetation of dry areas, in the long term it does not accomplish basic soil conservation goals. Bare areas remain between plants, causing soil erosion and resulting in characteristic "pedastaling". Crested wheatgrass does not produce as much root biomass as native grasses, resulting in less organic matter in the soil (Dormaar et al. 1978). This introduced plant suppresses recolonization by native grassland species and creates a forage stand that is not compatible for grazing with the surrounding native prairie. Crested wheatgrass also invades native mixed grass prairie. On the moister fescue prairie, the invasive nature of introduced grasses like brome grass has also been recognized.

Since 1990, Public Lands has requested the use of native species on prairie. However, only wheatgrass cultivars like northern, western, slender and streambank were available in sufficient quantity for reclamation projects. Even today, supplies of dominant grasses of the mixed grass prairie like needle and thread grass,. June grass and blue grama gras,s and dominants of the fescue prairie like rough fescue, bearded wheatgrass and western porcupine grass are in short supply and are very expensive. Add to that the problems with downy brome contamination of northern wheatgrass supplies, and you have a challenging situation.

The native "wheatgrass mix" that has been used in southern Alberta for the past five or six years tends to be seeded at very heavy rates to meet the 80% vegetation cover and density requirements of the wellsite reclamation criteria (introduced in 1994). There is a concern that such dense stands of one plant genus is

inhibiting recolonization by the local native plants. Public Lands is having reclamation sites on the mixed grass prairie evaluated by a consultant during the summer of 1996 to determine whether the vegetation criteria need to be altered to align more closely with our goal of eventual re-establishment of diverse vegetation on disturbed sites.

Developing more effective and practical revegetation strategies is the goal of a collaborative research effort by the University of Alberta, Alberta Environmental Centre, industry and Public Lands on wellsites in both the mixed grass prairie and the northern fescue prairie. Current mixes, alternate mixes and natural recovery methods will be tested in a five year project that began in 1996. Revegetation experimentation on major pipelines is also planned for 1997. Information that is gathered through this experimentation will be made available to all interested parties.

The northern fescue prairie has presented a particular area of concern because of its endangered status and the difficulty in re-establishing the major grass species, rough fescue, on disturbed areas. This grass does not recolonize easily from adjacent areas and seedlings do not seem to tolerate competition from other plants. Various strategies have been tried, including sprigging which is the harvesting and replanting of small pieces of crowns and roots. Sprigging was tried twice, once in the spring and once in the fall, without success. It appears that only highly rhizomatous species such as sweetgrass can be successfully propagated in this way. Native fescue hay was used on a wellsite in the fall of 1995 but the results so far do not look promising. Sod salvage will be tried on a section of pipeline in the fall of 1996. This method is likely to be successful, based on past research (Revel, 1993), however, the practicality of doing this on large areas or storing the material for long periods of time is in doubt. Seeding wild harvested seed collected near disturbances on the fescue prairie is another method that will be tested in the fall of 1996 or the spring of 1997.

Public Lands is committed to finding effective, practical and cost effective ways of reclaiming native prairie. Perhaps one day soon the supplies of native seed will be plentiful and the "platinum mix" will be a thing of the past. Sharing information is an important part of achieving our goal. Public Lands has published a book, "A Guide to Using Native Plants on Disturbed Lands"(Gerling et al. 1996) that lists many of the native plant species that are found on different site types in the various natural regions of Alberta. It is hoped that this information will assist reclamation practitioners in their work and seed growers in the business of developing commercial supplies of native plants. Working together we can successfully reclaim a valuable resource, our native prairies.

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MIXED-GRASS PRAIRIE HABITAT RESTORATION PROJECT: LANDSCAPE RESTORATION IN THE MOIST MIXED GRASS PRAIRIE[1]

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The Mixed-Grass Prairie Habitat Restoration Project (MGPHRP) is a joint venture of the Canadian Wildlife Service and Wildlife Habitat Canada, with funding from the North American Waterfowl Management Plan - Prairie Habitat Joint Venture, Environment Canada, and most recently from the Innovative Partnerships Program under the Canada-Saskatchewan Agriculture Green Plan Agreement. The project was initiated at Last Mountain Lake National Wildlife Area, Saskatchewan in 1992. The main objective is to re-establish and rehabilitate diverse native prairie habitat for migratory waterfowl and all other indigenous prairie species through appropriate restoration, rehabilitation, and management.

To implement this objective, it is necessary to develop or modify techniques for collecting, handling, processing, cleaning, and planting of native plant material suitable for the mixed-grass prairie. To rehabilitate degraded or neglected prairie habitat, understanding the appropriate use of fire and grazing management and/or use of chemical herbicides is necessary for the rejuvenation of prairie habitat and the control of exotic species.

The main driving force behind the establishment of the project is the extensive loss of prairie habitat. The remaining prairie habitat is fragmented into small islands surrounded by introduced vegetation. In addition, the removal of fire and unique grazing patterns, which are the major natural disturbances shaping prairie vegetation, has greatly exacerbated the problems facing the prairie ecosystem. The combination of these factors permits the buildup of excessive litter and the invasion of exotic species. This progressive transformation has left most of the remaining prairies to die a slow death. By reducing fragmentation through restoration and by maintaining or re-introducing natural ecosystem processes and disturbances, this continual loss and degradation of prairie habitat can be stopped and even reversed.

The MGPHRP has grown considerably since 1992 to become the largest prairie landscape restoration project in North America. The scope of the project has expanded to emphasize the development of techniques and protocols to facilitate the restoration and management of native prairie habitat. The benefits include:

- Development or rehabilitation of habitat for a wide spectrum of native prairie species to maintain and enhance biological diversity;
- Reversal of habitat fragmentation to protect ecosystems;

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[1] Presented at the 21st Annual Meeting, Canadian Land Reclamation Association, Calgary, Alberta, September 18-20, 1996.

[1] Présenté a la 21ème réunion annuelle de l'Association Canadienne de Réhabilitation des Sites Dégradés, Calgary, Alberta, September 18-20, 1996.

- Encouragement for planting lands with marginal soils to sustainable native vegetation.

PROJECT HIGHLIGHTS

- Planting of a 50 acre site to a diverse mixture of more than 50 species of native grasses and wildflowers (the largest diverse native planting in Canada)
- Annual seed collection from 60-70 species of native grasses and wildflowers
- Processing and storage of all native plant material on site
- 430 acres under preparation for native prairie plantings
- Grazing management initiated on 7 sites totalling ca. 3600 acres
- Fire management initiated on 14 sites totalling ca. 3700 acres
- Native cultivar grass monocultures totalling 160 acres established
- Development of a Volunteer Assistantship Program
- Preparation of a 60 acre native seed production nursery
- Joined forces with the Redberry Pelican Project, a non-profit environmental services corporation, to offer commercial services to agencies and individuals interested in prairie restoration and management
- Plans for a manual outlining procedures and protocols used, and results obtained, by the MGPHRP for:
  - flagging and mapping seed collection sites for each species;
  - timing and methodology for collection of seed material from selected species;
  - processing seed material from each species;
  - flowering and seeding phenology of selected native species;
  - collecting flowering and seeding phenology data;
  - restoration site preparation; species germination rates, between sites and years;
  - fire management for different vegetation management situations;
  - prescribed burns and burning;
  - grazing management;
  - exotic species control;
  - quadrat vegetation data collection along community transects and changes over time and under different management techniques; and
  - sites with different soil and moisture availability.

NATIVE PRAIRIE REGENERATION AFTER PIPELINE CONSTRUCTION - A COMPARISON BETWEEN TOPSOIL STRIPPING VERSUS NO TOPSOIL STRIPPING DURING CONSTRUCTION

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INTRODUCTION

Development of southern Alberta's natural gas fields often necessitates the construction of small diameter pipeline gas gathering systems across native prairie. Prior to pipeline installation through pasture or hay land, topsoil is routinely stripped from a 1.0 to 3.0 m width centred over the trench line (Mutrie and Wishart, 1987). Topsoil salvage is recognized as an important component of soil quality preservation during construction (Kerr et.al., 1993), and is especially important for reclamation of areas with highly saline/sodic subsoils. If saline/sodic subsoil material is mixed into the topsoil horizon, deterioration of the physical and chemical properties of the seedbed can occur to the extent that vegetation reestablishment is inhibited.

After construction, regeneration of native prairie vegetation on a pipeline right-of-way can often be restricted by lack of moisture and poor soil quality parameters such as low soil organic matter and fertility levels in the topsoil horizons (Kerr et.al., 1993). An alternative approach to minimize impacts on native prairie is to use as narrow a ditch as possible and forego salvaging topsoil to reduce the width of sod disturbance on the right-of-way. A trade-off exists in the degree and nature of negative impacts from pipeline construction where topsoil salvage is employed and a wider area of native sod is destroyed, versus construction where a narrow strip of topsoil is sacrificed in order to preserve more of the native sod. In assessing the impacts of pipeline installation through native prairie with saline/sodic subsoils, and in planning mitigative measures, it would be useful to have quantified information available concerning the degree and nature with which each of these two soil handling alternatives affect plant growth, soil quality and the rate of sod regeneration in disturbed areas.

To compare the effects of these two construction methods on regeneration of native vegetation, a long term monitoring study was initiated in November, 1993 during the construction of a PanCanadian Petroleum Limited pipeline project in the Dry Mixed Grass Ecoregion of southern Alberta.

METHODS

Prior to construction of the pipeline, three test strip locations were selected in native prairie areas. The test strips were located on Solonetzic Brown Chernozem soils of the Ronalaine series. Ronalaine soil profiles in the study areas are characterized by loam textured, non-saline non-sodic Ah (5 to 12 cm thick) and AB (7 to 12 cm thick) topsoil horizons, loam textured non-saline non-sodic Btnj (6 to 22 cm thick) upper subsoil horizons and loam textured saline/sodic Csk lower subsoil horizons (Pedocan Land Evaluation Ltd., 1993).

During construction, replicated treatments of approximately 100 m in length were established along the test strips to compare: (A) no topsoil salvage from over a 0.30 m wide trench; and (B) 1.3 m width topsoil salvaged to a depth of 25 cm from over a 0.30 m wide trench. Construction was completed to the backfill stage in December, 1993. Final clean-up and reseeding was postponed to the summer of 1994 due to winter weather conditions.

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During the summer of 1995, one year after reseeding, soil and vegetation parameters were measured along transects across the right-of-way on each of the replicated soil handling treatments. At each transect, five zones were sampled, corresponding to different activities or different degrees of impact associated with pipeline construction. Zone 1 is located over the trench line; Zone 2 is the spoil storage area on one side of the trench line; Zone 3 is the topsoil and spoil storage areas on the opposite side of the trench line from Zone 2; Zone 4 is the work and travel area of the right-of-way adjacent to Zone 3; and Zone 5 is the undisturbed area (control) located off the right-of-way adjacent to Zone 4.

Soil samples were analyzed for salinity (dS/m), sodicity (SAR), reaction (pH), macronutrients and organic matter content. Soil samples from Zones 1 and 5 (trench line and control) were taken from three separate depths (0-20, 20-40 and 40-80 cm). Soil samples from Zones 2 and 3 were collected from the surface horizon (0-20 cm) since no major disturbance of subsoil occurred in these zones. No soil samples were collected from Zone 4 (work area) since this area experienced only surface disturbance from traffic. Percent total plant cover and percent total plant cover were estimated within each sampling zone using a square metre grid. Statistical analysis of data from sampling sites was conducted using analysis of variance (ANOVA) procedures to determine significant differences among mean values for each parameter measured (Sokal and Rohlf, 1981).

RESULTS AND DISCUSSION

Soil sampling results indicate significant differences in soil chemical parameters among no-strip, strip and control treatments along the trench line (Zone 1) and the soil storage areas (Zones 2 and 3). The two most significant parameters measured impacting topsoil quality are EC and organic matter content.

On the trench line (Zone 1), at the 0-20 cm depth, mean EC values are significantly different ($p = 0.05$) among each of the two soil handling treatments and the control treatment (4.5 dS/m, no-strip; 1.3 dS/m, strip; 0.5 dS/m, control). At the 20-40 cm depth on the trench line, the EC values were significantly higher for both treatments over the control but were not significantly different from each other (4.1 dS/m, no-strip; 3.4 dS/m, strip; 0.7 dS/m, control). These results are consistent with the results reported by Leskiw and Burke (1995) from a similar study comparing no-strip and strip topsoil handling techniques during pipeline construction. Salvaging the topsoil horizon successfully reduced salinization of the seedbed along the trench line after construction. On the spoil storage sides (Zones 2 and 3) at the 0-20 cm depth, EC was increased on both soil handling treatments over the control as a result of saline subsoil remaining on the sod surface after backfilling. However, salinization in these areas was not as severe as along the trench line.

Total organic carbon (TOC) as an estimate of organic matter content was measured in the 0-20 m depth. No significant differences in TOC were detected at the 0.05 probability level, however, mean TOC on the trench line on no-strip treatments is significantly lower than the control at $p = 0.10$. Additions of straw to the right-of-way for erosion control after construction may have affected TOC values of topsoil samples and masked, to some extent, difference among soil handling treatments.

Vegetation regeneration was estimated by assessing percent total plant cover and percent moss/lichen cover on all sampling zones. On the trench line, spoil storage side and the topsoil and spoil storage side (Zones 1, 2 and 3), the percentage of total plant cover is significantly reduced for both stripped and no-stripped treatments in comparison to the control. However, in Zone 3 the moss/lichen cover of the stripped treatment is significantly reduced over the no-stripped control. On the workside (Zone 4), the percent total plant cover on the stripped treatment is significantly lower than the no-stripped treatment, possibly due to increased traffic during topsoil stripping.

These vegetative cover results indicate the possibility of an advantage in sod regeneration in no-strip soil handling in comparison to topsoil stripping during pipeline construction. However, these results are preliminary and monitoring over a longer period of time will be conducted to compare differences in the rate and species composition of native vegetation regrowth between the two soil handling techniques.

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RECOVERY OF NATIVE PRAIRIE AFTER PIPELINE CONSTRUCTION IN THE GREAT SAND HILLS REGION OF SASKATCHEWAN[1]

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ABSTRACT

A large diameter natural gas pipeline was constructed in 1990 through 12 km of the Great Sand Hills region of southwestern Saskatchewan. The harsh environmental conditions necessitated extraordinary construction and environmental mitigation measures to control wind erosion and successfully revegetate the highly erodible dune soils and fragile plant communities.

Mitigation measures included construction procedures that reduced the size of disturbance, public and worker educational extension programs, dormant season construction, topsoil seedbank salvage, placed fertilizer application, crimping weed free flax straw, straw bale wind barriers, brush mulch wind barriers, surface manipulation with the Hodder Gouger, fencing-out cattle, and the application of a seed mixture of agronomic legumes and native grasses. Vegetation and soil erosion was monitored for four years.

On low relief terrain (hills ca. 1 to 3 m high), vascular plant cover on and off the right-of-way (R/W) after 4 years was similar (44% vs 48%). However, on the high relief terrain (hills ca. 10 to 30 m high), the native vascular plant cover was 22% compared to 34% off R/W. Off the R/W, biomass production was consistent at all three sample sites averaging 165, 166, and 172 g/m^2. Results on the R/W were different, however. At the low relief sites, biomass production was almost twice that of off R/W (165 vs 288). The reason for this was a different species composition.

On the R/W, plant cover was composed mainly of native grasses from the revegetation mix whereas off R/W, a wider range of species was present including shrubs and forbs which do not produce much forage. At the moderate and high relief sites, biomass production was similar to off R/W. Low soil nutrients and dry climatic conditions limited the production of the forage species on the R/W. A major difference observed in the plant cover on and off the R/W was the presence of non-vascular plants (mosses and lichens) off R/W. This part of the prairie vegetative cover develops slowly.

Saskatchewan government reclamation standards were met for plant density, canopy cover, erosion control, and composition of native species (minimum 50%). The most successful sand stabilization treatment was a straw mulch applied at 6 to 9 t/ha and anchored by crimping. A brush mulch wind barrier of dead shrub branches salvaged prior to

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construction from sagebrush stands on the right-of-way was highly effective in controlling wind erosion on exposed sites. After four years, the canopy cover was 88% native species.

On low-lying, protected sites, vegetation was stable enough after 4 years to resume cattle grazing. Exposed sites on high-relief terrain may not be ready for cattle grazing for many more years.

THE EFFECTS OF GRAZING, MOWING, GLYPHOSATE AND BURNING ON SMOOTH BROME IN FESCUE GRASSLAND*

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BACKGROUND

Smooth brome (*Bromus inermis* Leyss.), was introduced to North America from Eastern Europe more than 100 years ago and is now valued for its high forage productivity and effective erosion control. However, its aggressive rhizomatous growth and prolific seed production enable it to invade native grassland and displace indigenous species. As smooth brome becomes dominant, biodiversity, winter forage value and habitat quality are reduced. Smooth brome invasion has important implications for grassland conservation because more than 80% of the Canadian native prairie has been lost to agriculture, the energy industries and urbanization (World Wildlife Fund Canada 1988). Only 10% of the fescue grassland remains, much of which has been modified by grazing and haying (World Wildlife Fund Canada 1988).

MATERIALS AND METHODS

In this study, sheep and cattle grazing, mowing, glyphosate wicking and early spring burning were combined to potentially weaken smooth brome and thereby enhance the competitiveness of native plants. Over two growing seasons (1994 and 1995), twelve treatment combinations were applied to four blocks in a randomized complete block design. The blocks were located on smooth brome dominated areas adjacent foothills fescue grassland on south facing slopes in the Ann and Sandy Cross Conservation Area, 3 km west of Calgary, Alberta. The hot dry south facing slopes were thought to be the most likely place to stress and weaken the moisture and nutrient loving smooth brome. A single grazing, whether by sheep or cattle late in the first summer, was followed by sheep or cattle grazing (3 times) or by mowing (2, 3, or 4 times) in the second growing season. All grazing was heavy, except for one sheep treatment where the midsummer grazing intensity was lighter to allow the native grasses greater recovery time. A 2:1 solution of water:glyphosate was selectively applied to smooth brome using a hand-held hockey stick wick applicator. Selective application was possible because smooth brome was taller than most other plants present. A single mid-summer glyphosate wicking in the first year was followed in the second year with further glyphosate application (1 or 2 times), mowing (3 times), or early spring strip headfires combined with more herbicide (2 times) or mowing (3 times). Reference plots, where no management action was taken, were also included in the experimental design.

Species composition was assessed in 10 randomly located permanent 0.1 m^2 quadrats per plot prior to treatment implementation (July 1994) and at the end of the second growing season (September 1995). Tiller density was counted in 5 stratified random permanent 0.1 m^2 quadrats per plot in July 1994, September 1994, May 1995 and September 1995. Soil plant cores (6 per plot) were collected at the end of the study for analysis of etiolated regrowth and total nonstructural carbohydrates (expressed as % fructose) of smooth brome.

RESULTS AND DISCUSSION

Smooth brome decreased in all treatments over the course of the study. Minimal change occurred in the reference plots (-2%), whereas maximum change was effected by glyphosate treatments (-29 to -51%). Defoliation, whether by cattle, sheep or mowing removed a large proportion of smooth brome biomass (-13 to -29%).

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Smooth brome tillering was stimulated by three or more summer defoliations by cattle (37%), mowing (42%) and sheep (50%). Generally the more frequent and intense the defoliation, the greater the increase in tiller density (up to 75% in the case of three heavy sheep grazings in the second year). Mowing only twice in the second year caused minimal change (6%), similar to the change observed in the reference (7%). Herbicide impact on smooth brome tiller density quickly diminished over time. In September 1994, after one mid-summer application of glyphosate, smooth brome tiller density was reduced 68%. One year later, with one or two additional glyphosate applications in the second growing season, smooth brome tiller densities were only 25 to 42% less than pretreatment densities. There was no significant difference whether glyphosate was applied once or twice in the second year. Although early spring burning removed litter, it did not stimulate smooth brome growth and improve herbicide efficacy as anticipated (Grilz 1992). Rather, the burn stressed smooth brome which was just beginning to grow. Tiller stimulation by three mowings in the second year more than compensated for the original decrease caused by herbicide in the first year (net 20% increase). When burning was combined with mowing, a slight decrease (-8%) in tillers occurred. However, it is unlikely that this decrease was directly due to the effect of the burn but rather the indirect effect of increased competition by Kentucky bluegrass (*Poa pretensis* L.), the subdominant species, whose tiller densities increased 249% from 539 to 1924 tillers m^{-2}. Kentucky bluegrass was dormant at the time of the burn and is very tolerant to mowing. Although not as dramatically, Kentucky bluegrass tiller density and species composition increased in all treatments, including the reference.

Etiolated regrowth and total nonstructural carbohydrates were not statistically different among treatments. However, etiolated regrowth from reference plot samples was greatest, indicating somewhat greater energy reserves.

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

Glyphosate wicking effected the greatest decrease in smooth brome tiller density over the course of the study. However, in order to protect the desirable species, not all smooth brome could be contacted and reapplication will be necessary. Further follow-up is required to determine the longevity of the effect on smooth brome tiller density and whether the reduced tiller density facilitates increased competitiveness in native species. Heavy defoliation to stimulate tillering and growth prior to glyphosate application may increase herbicide effectiveness. Where there are few native species, it may be more effective to spray the entire area with glyphosate and reseed with desirable species.

After two seasons of defoliation, smooth brome did not appear severely stressed as evidenced by tiller stimulation, carbohydrate reserves and etiolated regrowth. Although, sheep and cattle selectively graze smooth brome over the harder native fescue in the summer, heavy grazing pressure causes almost all species present to be grazed. Several years of frequent heavy grazing or close mowing may reduce smooth brome tiller density, however, many desirable species may also be reduced.

To fully evaluate management options, research is needed to determine the impact of treatments repeated for several years on all species in the plant community. Plant physiological stage at time of treatment implementation must be carefully considered.

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AVOIDING DOWNY BROME WHEN BUYING SEED

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WEED TOLERANCE IN SEED ACT AND WEED ACT

Seed is grown and harvested, cleaned, graded, and placed on the market according to regulations set out in the Canadian Seeds Act. Included in this act is the weeds list divided as follows:

- noxious weeds
  - prohibited weeds
  - primary weeds
  - secondary weeds
- other weed seeds

Specific weeds are listed in each category. Prohibited weeds can generally be thought of as perennial and often poisonous. eg. western water hemlock or diffuse knapweed. Primary noxious weeds are mostly perennial and very difficult to control. eg. perennial sow thistle, Canada thistle and wild mustard. Secondary noxious weeds are difficult to control, but not as difficult as the primary weeds, and include more annuals. Examples are wild oats, dog mustard, and scentless chamomile.

All weeds not listed as noxious are considered "other weeds". Downy brome is considered an "other weed". Although some counties have listed Downy Brome as prohibited or restricted or something, seed is bought, sold, and regulated by the Federal Seeds Act only.

There is an Alberta Weed Control Act which also has a list of weeds, separated as restricted, noxious and nuisance weeds. This Provincial Act gives the province the ability to enforce weed control on land owners.

The two lists are very similar. The restricted weeds on the Alberta Weed List include the prohibited noxious on the Federal Act. The noxious Alberta Weed List includes weeds from the primary and secondary noxious weeds on the Federal Act. But not entirely. There are a few discrepancies. Quackgrass, wild oats, scentless chamomile and downy brome do not coincide on both lists.

The county may also pass weed control by-laws independent of the Alberta and Federal Acts. Again these by-laws are for the enforcement of weed control of certain weed species.

CERTIFIED SEED AND OTHER CLASSIFICATIONS

Seed used for Reclamation purposes are classified as Canada Foundation No. 1 and No. 2, Canada Certified No. 1 and No. 2 and Common No. 1 and No. 2. Each classification represents a generation of seed production. Common seed is grown from certified seed which is grown from foundation seed.

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The designation of No. 1 or No. 2 is determined by the seed quality, purity and germ of the seed. The classification also includes seed quality; for example, common seed has a higher weed tolerance than certified seed. It is also very possible however for common seed to be weed free and even downy brome free yet remain as common seed. The determining factor for common seed is whether it was grown from certified seed rather than foundation seed.

Not all certified seed is created equal. Seed is cleaned and processed by seed lot. Each seed lot is individual, with its own origin, amount of weeds and other crops, types of weeds and its germination. For example, two lots of Walsh Western Wheatgrass may be graded as certified No. 1 but they differ with purity and germination. The certificate on each seed lot gives the details of the weeds, germination and other particulars.

SEED CERTIFICATES

A seed certificate is the result of the analysis of a seed lot. It shows the level of weed contamination and lists the species. Similarly, a certificate shows how much other crop seed is in the seed lot and lists the crop.

The analysis of a seed lot is not 100% accurate. A 45 gallon drum of HCL can be analyzed with 100% accuracy with a teaspoon full of the solution from the top, bottom or anywhere in that drum. Seed is not in a homogenous solution. Seed is more like people congregated is a room - each person is different and individual.

The problem arises when a seed certificate shows 1 to 5 seeds found of a weed species. What does this represent? Does this mean there will be 5 weed seeds uniformly spread among the 5000 to 12,000 crop seeds, or does this mean the analysis picked up a small cluster of weed seeds, and there are virtually none in the remainder of the seed lot? What happens when a certificate shows zero weeds or zero downy brome? Did the analysis happen to miss the 1 to 5 weed seeds in 12,000 crop seeds or are there actually absolutely no weeds in that seed lot? What does the certificate guarantee?

Basically a seed company, even Prairie Seeds, can only guarantee that the certificate is representative of the seed lot purchased. If you want zero downy brome in your seed, the seed company can only guarantee that the certificate shows zero downy brome, not that there will be zero downy brome in the seed lot.

HOW DO YOU AVOID DOWNY BROME?

The more people involved between the person doing the seeding and the person buying the seed, the greater the chance of getting downy brome.

If the Government writes the seed mix specifications, the pipeline reclamationist approves the purchase of that mix, he in turns farms it out to a consultant to purchase that seed, who hires a company to do the seeding and pick up the seed . . . there will be problems. If you stick a purchasing agent into this mix, there will be problems. Why? Because the person who finally talks to the seed company does not have a vested interest in the quality of the seed mix.

When the person writing the seed specs talks to the seed company . . . magic happens. Questions like "Is this mix going into a downy brome free area?" can be asked and answered. "Does the seed mix call for strictly native seed?", and most importantly, "There is no Sodar Streambank available without downy brome. Would you like to use a common streambank, or an Elbee Northern Wheatgrass or should we just throw in some crested?"

The above is not a fabrication. Very often in a chain of command of 6 or 8 people, between the person who plans the seed mix to the person who buys the seed, one of them will suggest "throwing in crested or bromegrass" if there are difficulties in getting the specified seed.

Time is the next factor that will determine how much downy brome you want. Take the first example of the government specification to pipeline company to consultant to seeding contractor, add in "we will be there tomorrow to pick it up", this multiplies the downy brome probability.

Why? The time constraints prevent any back tracking to those with vested interest in the seed mix to suggest alternatives. Also, there is no time to bring into the warehouse another lot of seed that meets the specifications. And finally, if the contractor and consultant have screwed up that badly, that the seed is needed yesterday, neither of them would know or care if bromegrass, crested wheatgrass or festuca saximontana was used in the seed mix.

So how do you buy seed without downy brome? Get the person who cares about the project to talk to the seed company.

BIODIVERSITY AND RECLAMATION: HOW MANY SPECIES DO WE NEED IN A SEED MIX?[1]

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ABSTRACT

Ecologists have long debated the role of diversity in the stability of ecosystems. One focus of the debate asks whether all the species in an ecosystem are necessary, or if there are redundant species that can be lost with impunity. In reclamation, the question is reversed - what is the minimum number of species necessary for a stable productive ecosystem?

Researchers demonstrated that, in an artificial environment, high diversity communities consumed more CO_2, had greater productivity and greater cover. Recently researchers in Minnesota demonstrated that a minimum of ten species were necessary for maximum productivity and nitrogen use in the Great Plains.

Research at the University of Alberta examined the effects of ten seed mixes varying in species and genera richness on cover, species composition and weed invasion. During the first two years of the field study, increasing richness had little effect, however, three seed mixes were significantly different due to the presence of *Agropyron trachycaulum, Bromus anomalus* and *Poa palustris*. It is clear that some species are more competitive than others and can effectively out-compete even a diverse seed mix.

Current research indicates that the selection of species affects the cover and species composition in the first two years. In addition, seed mixes should have a minimum of ten species to maximize productivity, but more than ten species should be used to allow for variability in site conditions and weather patterns.

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EMERGENCE AND SURVIVABILITY OF SELECTED NATIVE AND INTRODUCED GRASSES AND LEGUMES*

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BACKGROUND

There is renewed interest in the use of native plant species and their performance for reclamation and agriculture, but little information is available to indicate how they perform compared to introduced plant species. Emergence and survivability data for native species is particularly sparse. Germination data and tetrazolian tests from seed laboratories are more readily available but may not be a true indicator of species performance under field conditions where local climate and site conditions affect plant growth. Field data on emergence and survivability, especially combined with management treatments, could have profound effects on seeding rate and seed mix recommendations. Thus objectives of this research were to evaluate and compare emergence and establishment of selected native and introduced plant species mixes and to evaluate their response to specific management inputs of mowing and herbicide application.

MATERIALS AND METHODS

21 introduced and 14 native plants commonly found in the aspen parkland ecoregion were seeded at the Lacombe Research Center of Agriculture and Agri-Food Canada. Species mixes were seeded in a randomized complete block design at a 1.27 cm depth with four replicates (blocks). Mixes were comprised of six species each; four mixes were of native species, four were of introduced species and one was a mix of native and introduced species. The introduced species were: northern wheatgrass, tall wheatgrass, intermediate wheatgrass, western wheatgrass, slender wheatgrass, pubescent wheatgrass, creeping foxtail, meadow foxtail, Dom Frederico bromegrass, smooth bromegrass, dahurian wildrye, orchard grass, meadow fescue, perennial ryegrass, Algonquin alfalfa, Anik alfalfa, Rangelander alfalfa, timothy, Canada bluegrass, Kentucky bluegrass, alsike clover and fall rye. Native species were: Parry's oatgrass, tufted hairgrass, foothills rough fescue, plains rough fescue, idaho fescue, june grass, purple prairie clover, western porcupine grass, green needle grass and american vetch. Four mowing treatments were conducted (early season, late season, early and late season and a no-mow control). Early season mowing was conducted when the majority of the weeds present were in bloom and the majority of the seeded plant species were below the height of the cut (11.25 cm). Late mowing was conducted near the end of the growing season. Three herbicides (Pardner, Embutox and Banvel) as well as a control were applied as recommended by the manufacturers.

PRELIMINARY RESULTS

Emergence of native species was generally lower than introduced species. However, emergence was lowest for smaller seeded species of both groups and highest for large seeded species, reflecting that smaller seeded species may require shallower or broadcast seeding. There was no distinction between response of native and introduced species to mowing. However, both groups of species responded to mowing treatments similarly. Early and late season mowing reduced competition from weeds the most and resulted in a higher percent survivability of both native and introduced species the following year. Survivability was lowest with late season mowing. Response to herbicides was species specific with no trends between the native and introduced species.

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ROAD MAPS FOR REPAIRING ECOLOGICAL DEGRADATION[1]

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ABSTRACT

The expansive habitation of our planet has lead to considerable ecosystem disturbance and degradation. Many ecosystems, ranging from tropical rainforests to native prairie have become endangered. The loss of these ecosystems is accompanied by a reduction in biodiversity, habitat, and potentially sustainability. Ecologists have therefore aspired to protect the remaining 'undisturbed' ecosystems, and re-establish 'traditional' ecosystems on anthropogenically disturbed lands. As this is a relatively young science, there is significant variability and dispute over the nature and use of terms which describe the process of returning an ecosystem to it's traditional structure and function. Such terms include reclamation, restoration, rehabilitation, remediation, reconstruction, recreation, and naturalization. A clear definition of these terms and the context in which they are being used is critical since they represent the goals (i. e. road map) of the reparation process being employed. The nature and use of a select group of these terms will be discussed in this presentation.

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ECOVAR DEVELOPMENT IN WESTERN CANADA

Les Wetter and Brent Wark

Ducks Unlimited Canada

Ecovar Development Program

Native plant species provide attractive wildlife cover. Once established, native species are long-lived, self-propagating and inexpensive to maintain. Revegetation using native species is consistant with DU's philosophy of promoting biodiversity.

Ducks Unlimited launched Canada's first ecovar program in 1991. The goal is to obtain, through the development of ecovars, adequate commercial seed supplies of native species to meet the growing demand for reclamation and revegetation.

Cultivars and Ecovars

A cultivar (cultivated variety) is a group of plants selectively bred over many plant generations to achieve uniformity and enhance production. Most of the current agricultural crops grown, including tame grasses, are cultivars.

An ecovar (ecological variety) is an intermediate step between the true native population and a cultivar. Ecovars are the progeny of native plants gathered from their area of adaption and contain the natural genetic diversity of the species. The ecovar selection process is short. Plants are gathered and seed sent for commercial production in as little as four years.

The Selection Process

Plants are gathered from sites across western Canada within the natural eco-region of each species. The plants are then transplanted or seeded at several locations within the eco-region. Agronomic and seed production data is collected to describe the population and discard plants unsuitable for an ecovar.

The plants are established in a pattern that allows for the natural pollination pattern of the species which maintains the biodiversity within the population. The main criterion for the plants included in the ecovar is to be able to produce sufficient viable seed to be economical for commercial seed growers.

Care is taken to maintain most, if not all, of the characteristics of the native species. Therefore, other traits such as biomass production is a much less important criterion to select plants for ecovar develoment. The concern is more to maintain a biologically diverse ecology than with increasing forage production.

Seed produced from the plants within the population becomes the ecovar for that species and is released to seed growers to supply reclamation and revegetation needs.

Partnerships Make It Work

Monsanto became the founding sponsor of the ecovar development program with their generous contribution of $100,000 in 1993.

Agriculture and Agri-Food Canada participates in the program at research facilities at Brandon, Manitoba; Swift Current and Saskatoon, Saskatchewan and at Lethbridge, Alberta. Development of ecovar shrubs is taking place at the Prairie Farm Rehabilitation Administration's shelter belt centre at Indian Head, Saskatchewan.

The US. Natural Resources Conservation Service, the University of Manitoba in Winnipeg and University of Saskatchewan in Saskatoon, are also partners in the ecovar development program. Ecovar development is also underway at the Alberta Environmental Centre at Vegreville.

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Ecovars Currently Under Production

The following list shows ecovars which are currently under development from Canadian collections.

Spangletop
June Grass
Little Bluestem
Needle-and-Thread
Porcupine Grass
Green Needlegrass
Plains Rough Fescue
Blue Grama
Prairie Sandreed
Prairie Cordgrass
Awned Wheatgrass
Western Wheatgrass
Northern Wheatgrass
Purple Prairie Clover
White Prairie Clover
Winterfat
Snowberry
Woods Rose
Shrubby Cinquefoil
American Hedysarum
Reed Grass
Canada Wildrye
Hookers Oatgrass
American Vetch
Indian Rice Grass

PLANT GROWTH ON AGGREGATED OIL SANDS PROCESSING RESIDUES

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ABSTRACT

A greenhouse experiment was conducted to evaluate plant performance on the aggregated oil-sand processing residues. Seedlings of three species, "AEC Highlander" slender wheatgrass (*Elymus trachycaulus subsp. trachycaulus*), alpine milkvetch (Astragalus alpinus L.), and saskatoon (*Amelanchier alnifolia, smokey*), were transplanted into aggregates made from: (1) MFT(mature fine tails):CT(composite tails)(1:1 ratio) amended with 5, 10, and 15% peat moss, and (2) MFT:TS(tailings sand)(1:1 ratio) amended with 5, 10, and 15% peat moss. Standard land reclamation coversoil material was used as a control. For each species, the growth rate, total shoot and root dry mass were compared among the aggregate treatments. The growth of slender wheatgrass showed no significant differences among treatments. The growth of Saskatoon seedlings increased with increasing peat moss in the aggregated materials. Alpine milkvetch performed poorly on all the treatments. This was attributed to sensitivity of milkvetch to the high salt contents in the aggregated residual materials. This study indicated that it is possible to create a plant growth medium using oil sands processing residues.

INTRODUCTION

The establishment of self-sustaining ecosystems is a major challenge in the reclamation and restoration of oil sands processing residues. The primary residues consist of coarse tailings sand (TS), mature fine tails (MFT), and composite tails (CT). It is extremely difficult to establish a plant community on these materials without first improving their physical structure (Monenco Consultants Limited, 1983). We had demonstrated that a suitable soil structure could be created by blending these materials through an artificial aggregation process (Li and Fung, 1996). The objective of this study was to evaluate plant growth on these aggregated oil sands processing residues in a controlled environment.

MATERIALS AND METHODS

Two plant treatments, "AEC Highlander" slender wheatgrass *(Elymus trachycaulus subsp. trachycaulus)* plus alpine milkvetch *(Astragalus alpinus L.)* and saskatoon *(Amelanchier alnifolia, smokey*, were used to evaluate plant establishment and growth in six aggregated materials. The materials were MFT(mature fine tails):CT(composite tails)(1:1 ratio) amended with 5, 10, and 15% peat moss and MFT:TS(tailings sand) (1:1 ratio) amended with 5, 10, and 15% peat moss. A standard land reclamation coversoil material was used as a control. Plant seedlings were grown in plastic containers (29 cm diameter × 45 cm height) in a greenhouse. The bottom 20 cm of all containers were filled with CT materials at approximately 1.1 g cm^{-3} bulk density to simulate a subsoil. Twenty (20) cm of aggregated materials or control material, with a bulk density of 1.1 g cm^{-3}, were placed on top of the CT materials. All treatments were replicated three times. One set of containers (21) had two seedlings of "AEC Highlander" slender wheatgrass and one seedling of alpine milkvetch grown together in each container. A second set of containers (21) had two seedlings of saskatoon grown in each container. Initially, 200 ppm N and 80 ppm P were applied to all the treatments. After transplanting, all treatments were watered to "field water holding

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capacity', approximately 28% by volume. During the growth period, water content was maintained at 18 to 20%. The height, leaf and tiller number of plants were measured during the growth period. Plants were harvested at day 130. Biomass, including shoot and root mass, was measured. Roots in the top layer of the aggregated materials and the bottom layer of CT were measured separately.

RESULTS AND DISCUSSION

For "AEC Highlander" slender wheatgrass, the total root dry mass showed no significant differences among treatments. More than 40% of total root dry mass was grown in CT materials for all the treatments. This would enhance the development of CT materials and contribute to the development of a sustainable plant community. The height of slender wheatgrass also showed no difference among treatments. The total shoot dry mass of slender wheatgrass grown in the MFT:TS with 5% peat moss was significantly lower than that in the control and MFT:CT materials. The lower shoot dry mass was due to the lower tiller number. The higher peat moss (15%) in the MFT:TS treatment did not improve shoot dry mass. This could have been due to higher microbial activity which competed for nutrients in this treatment. Alpine milkvetch also performed poorly in all the treatments as compared to the control. This can be attributed to the sensitivity of milkvetch to high salt contents in the aggregated residual materials. There was significant growth reduction in saskatoon seedlings in the aggregated materials as compared to the control. An increase in peat moss improved both shoot and root growth of saskatoons. Although saskatoons did not perform as well as slender whatgrass, they showed significant improvement as they grew older.

In conclusion, this study indicated that it is possible to create a plant growth medium using oil sands processing residues. However, research should focus on the selection of salt-tolerant plant species as well as the ways of reducing salt levels in the soil profile.

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THE CLOVER BAR LANDFILL
A STATE OF THE ART LANDFILL RECLAMATION PROCESS

Ann Smreciu[1], Nolan Turner[2], and Don Barron[3]

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INTRODUCTION

The Clover Bar Landfill, located in northeast Edmonton, is situated along the North Saskatchewan River. The site was opened to receive solid waste in the 1970's. The first phases were closed and capped in the early 1980's. In keeping with standards of the day, the area was covered with a shallow layer of topsoil, a mixture of agronomic grasses, and a few ornamental trees for beautification. The result was visually unappealing and ecologically unstable. The site required large inputs of resources for maintenance.

A revised, long-term revegetation plan for the Clover Bar Landfill Site was developed by Landscape Architect, Don Barron, in collaboration with Agrologist, Nolan Turner. A comprehensive site evaluation highlighted the need for mitigation of several site conditions that could discourage or limit plant growth and development. These included: toxic substrata materials, an impenetrable clay cap, shallow topsoils, soil component deficiencies and/or excesses, poor moisture conditions due to slope design and persistent high winds, and an extensive agricultural weed problem from on-site and from numerous adjacent sites. The reclamation plan outlined a series of unique methods to mitigate these conditions. This site was also recognized as a major movement corridor and safe refuge (from man and his activities) for wildlife from nearby natural areas.

DESIGN

Maintaining ecological and aesthetic integrity of the North Saskatchewan River Valley Park System was a guiding factor in the design process for the Clover Bar Landfill. The design was based on accelerating natural succession by establishing key plant species and recommended the establishment of numerous, strategically placed 'nuclei beds' planted with a heterogeneous mix of native trees, shrubs, and herbaceous perennials.

Phase 1 was designed as a trial to supplement the limited information available regarding the most efficient use of native species and the best production and planting methods. A short-term maintenance program was designed to encourage establishment and development of a sustainable, self-perpetuating, native 'Urban Forest' ecosystem

Principles of recycling and reuse were incorporated into the reclamation plan. Materials recommended for use on-site (topsoil, compost, sewage sludge, and mulch) were recycled from other projects and programs. Plant materials were collected in areas slated for development and

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irrigation water was obtained from the existing ground water diversion system on the periphery of the site.

PLANT MATERIALS

Approximately 25 species of woody plants were placed in Phase 1 trial beds. Trees and shrubs were produced by one of three methods. The first was to salvage small, mature plants from areas that would likely be disturbed. Plants were either moved directly to planting beds or maintained in the nursery (in pots) for three months where they were fertilized to encourage significant root development. The second method was by various cuttings. Pole and hardwood cuttings were placed directly into planting beds in spring whereas softwood cuttings were rooted in the nursery prior to being set out. The third propagation method was by seed which were sown directly in planting beds on site or sown in styroblock containers and maintained in the greenhouse until sufficient root and top growth developed. Herbaceous perennials (representing 15 species) were grown in styroblock containers in the greenhouse from seeds or cuttings.

To ensure adaptability of plants to local conditions, indigenous plants used for planting at Clover Bar Landfill were collected within the immediate area (a radius of 50 km).

CONSTRUCTION, PLANTING, AND MAINTENANCE

Construction of Phase 1 beds was completed in 1993. Phases 2 and 3a were completed in 1994 and 1995 respectively. Bed areas were mowed and existing vegetation and substrates were removed. Beds were refilled to a depth of approximately 30 cm with topsoil combined with sewage sludge and compost. Planting of Phase 1 began in late summer, 1993 and completed in 1995. Phases 2 and 3a were planted in 1995.

Mulch was placed in each area soon after planting. Plants were watered immediately and continued to be irrigated as necessary. Large weed populations had developed on the site (and on adjacent lands) prior to beginning the reclamation process and an intensive weed control program began in June 1994. Planting beds will be weeded for up to three years as required to provide a competition-free environment for native plants to establish well developed root systems. Control measures for other pests and diseases were only taken if survival and establishment of the native plants was likely to be compromised.

MONITORING

Wild Rose Consulting, Inc. was retained in 1994 to design and implement a vegetation monitoring system. The objectives of the monitoring system were to determine if the plant materials and the methods used to produce, install, and maintain plant materials would provide the desired results (i.e. a dense cover of a variety of plant species of diverse age). Two types of data were collected to determine the success of the planting beds. The first was to measure and assess the success of each group of species and planting material type. Assessment parameters included emergence (for seeds), survival, and vigour of plants. The second type of data recorded were observations of natural recruitment or natural invasion by indigenous species from surrounding and adjacent native areas. Data were collected in 1994, 1995, and 1996 and analysed annually. Results are used to re-evaluate designs on an on-going basis.

RESULTS

Salvaged plant material of most species performed well; they exhibited high survival rates. The advantage of this method is that resulting plants were vigourous and several were spreading (some at rates up to 1.5 m per year). Styroblock material generally survived well in the first year, but many of these plants but were not necessarily vigourous. Species raised in styroblock containers were small and take several years to provide the desired vegetation cover; particularly with species that do not spread by root shoots or rhizomes. Plants grown from cuttings showed variable results.

Several species established well from seeds sown directly in the planting beds but seeding results were variable. Seedlings take several years to develop into large plants that provide a dense cover. During this time weeds must be kept to a minimum and maintenance costs can escalate. Seeding could be particularly effective if used in combination with other methods (e.g. seeding under sparsely planted mature material).

Numerous native plants became established in planting beds by seed spread from existing native stands adjacent to the site. This was especially prevalent in the lowest beds on the north aspect where the beds were only metres from existing native stands along the river. Some of these trees and shrubs that established in 1994 had grown to a height of over 3 metres by 1996. Approximately 20 herbaceous species also became established in various beds.

CONCLUSIONS

Approximately 50,000 plants were installed in planting beds in the first three phases of the project; over twice this many have emerged from root sprouts, from seeds produced by the initial plant material, or have migrated from surrounding native plant communities. Phases 2 and 3a planting designs were revised to accommodate the higher than expected emergence and survival rates and plant vigour observed in Phase 1. The thriving plant material of the early phases will provide much of the green stock required for the balance of the project (Phases 3b, 4, and 5). Continued monitoring of plant establishment and growth (and more particularly the development of integrated plant communities) will provide a significant amount of information that can be applied to future phases to further reduce costs and increase the potential for success.

The success of plantings in Phase 1 has been extraordinary. In spite of very difficult site conditions and numerous constraints, heterogeneous, dense thickets have developed. These 'Urban Forests' are continuing to evolve and become more complex as additional plant species migrate into these areas and as various wildlife species (deer, rabbit, fox, coyote, and many songbirds) begin to utilize them for food and cover.

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A METHOD FOR CHARACTERIZING THE BULK DENSITY OF COMPRESSIBLE PARTICULATE MATERIALS

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INTRODUCTION

Any description of a material would be incomplete without consideration of the physical properties of that material. For materials that exist as particles in a bulk, the properties of the bulk material are often as important as properties of the individual particles, and perhaps the most basic bulk property is that of bulk density. This is simply defined as the mass of a bulk material divided by the volume that the mass occupies.

For relatively hard materials, such as soil or grain, measurement of bulk density can be carried out very simply by measuring the mass of material required to fill a container of known volume or measuring the volume occupied by a known mass of the material (Mohsenin 1986; Stroshine and Hamann 1994). If the particles are incompressible, this can be assumed to give the maximum bulk density of the material. However, if the material is compressible, bulk density values obtained from small, disturbed samples will reflect only the properties of material on the surface of a bin or pile. Material at some depth will have higher bulk densities due to compression under the weight of the material above it. This could be of significance in determining the mass of material in a pile of a given volume, in the estimation of other physical parameters (such as thermal conductivity, porosity, or resistance to air flow) deep within piles of such a material, or in the design of storage structures and materials-handling systems.

Consequently, the first problem of characterizing the bulk density of compressible materials is how to obtain a value at any location in a pile. This invariably involves disturbing the sample to some extent, or disturbing the surrounding material so that the load on the sample is changed, or both. This paper describes an alternative approach in which the loading at any depth in the bulk is simulated to obtain a relationship between depth and bulk density. This relationship can then be used to derive a value for the effective bulk density of the entire mass of material.

The objective was to develop a laboratory method of characterizing bulk density that was cheap, simple, precise, and accurate. Since it has the potential to be applied to a wide range of materials, the approach was tested with compost, wood shavings, straw, and peat moss.

METHOD

The basic apparatus required was a container for the material, a set of weights with which to apply vertical loads, and a platform scale. In order to minimize wall effects, a large steel cylindrical container, approximate diameter 500mm and height 750mm, was used. However, this container size was too large for practical in-field use. Therefore, smaller containers have been designed using schedule 40 pipe (approximate diameter 300mm and height 400mm). Results using the small containers are not available at this time as data are in the process of being collected.

The containers were weighed and a line was marked on the inside, from the bottom. Material was filled to the 500mm mark for the larger container and to the 250mm mark for the smaller container. The containers were filled with water to these marks and weighed. Assuming the density of water to be 1000 kg/m^3, the volume of the container to the mark ($V_{500\ or\ 250}$) was determined.

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The material to be measured was placed in the container to a level exceeding the mark and shaken to ensure that the material settled. Material above the mark was removed then the container was weighed and the bulk density (D) of the material was determined.

This represents the bulk density in the top 500mm or 250mm of a pile. The next step was to determine the bulk density in the next 500mm or 250mm layer. To do this, a load equivalent to the mass of material was applied to the material in the container, by placing known masses on top of the material. To ensure uniform loading, the masses were placed on a plywood disk with the diameter slightly less than the container. This loading compressed the material and was applied for about one hour so that the material could consolidate to a constant volume.

Compression distances were measured and the values used to determine how much material needed to be added to bring the level back to the mark. After adding this material, and after a 1 minute consolidation time with the load applied, the level of material was checked to see if it was at the selected mark. Adjustments were made as required adding or subtracting material until the level was at the desired mark. The added mass plus the previous mass of material represented the final mass of the second layer.

The above procedure could be repeated for any number of layers. In general, the bulk density (D_n) of the nth layer is given by:

$$D_n = \frac{M_t - (M_c + \sum_{i=0}^{n-1} M_{mi})}{V_{500 or 250}} \text{ kg/m}^3 \qquad (1)$$

Where:

M_t = Total mass of the material and container

M_c = Mass of the container, and

M_m = Mass of material in ith layer

= Mass of applied load

The trials conducted were repeated, layer by layer, to a simulated depth of 3.5m (1.75m for the small containers) and resulted in a set of bulk density determinations corresponding to successive 500mm or 250mm layers of material. These were plotted against depth and a least-squares regression routine was used to fit curves to the plotted points.

Once a bulk density versus depth curve had been obtained, an effective bulk density (D_{eff}) could be defined as the bulk density which, if constant with depth (z), would give the same area under a bulk density-depth curve as the experimental values.

This is expressed mathematically in Equation 2 as follows:

$$Deff = \frac{1}{z} \int_0^z D(z)dz \text{ kg/m}^3 \qquad (2)$$

RESULTS AND DISCUSSION

The method of bulk density characterization presented above was conceptually simple and did not require any expensive or particularly sophisticated equipment. Results from the large container experiment, tested in two separate trials, indicate similar trends in describing the characteristics of the materials tested and the density as a

result of a load exerted upon the material. This was seen by the similarity between equations to curves for like materials and the high R^2 values ranging from 0.88 to 0.99.

In fitting curves to the data, the selected best-fit equation was a power function, of the form $y=Ax^B$. This regression equation was selected as its could described the behaviour or properties of materials. Thus, y represents the bulk density, x represents depth, and A and B are constants that depend on the material.

The coefficients (A) provide an indication of the order of magnitude of the bulk density of the material. The exponents (B), on the other hand, give an indication of the compressibility of the materials. The higher the exponent, the higher the compressibility. A completely incompressible material whose bulk density was constant with depth would have an exponent of zero. Examination of the equations shows that wood shavings was the least compressible of the materials tested and had a minimum exponent of 0.0518, while compost was the most compressible material and had a maximum exponent of 0.28.

Of the materials tested, the most variable was compost. This may have been due to the physical differences of the material being initially compressed and the material having had another year for decomposition. On the other hand, peat moss had the least variance which may be explained by the relatively homogeneous and stable make-up of peat.

Although power function equations, as described above, provide a convenient description of the bulk density of compressible materials, practicality demands a single number to characterize this property. Effective density (D_{eff}) is proposed as this number on the grounds that it is more representative and, potentially, of greater practical significance than a simple average of a number of measurements. By definition, determination of D_{eff} requires measurements of bulk densities at a range of compressions and, the larger the range, the better will be the estimate of D_{eff}. This encourages a complete characterization of the behaviour of the material rather than simply taking a few measurements at the surface or at low levels of compression which are not representative of most of the bulk.

The formula for D_{eff} (Equation 2) is based on the area under the density-depth curve. This area has units of kg/m^2 which, by multiplying by grams, is easily converted to N/m^2 and, thus, is an indicator of the vertical load exerted by a pile of material with a height corresponding to the integration interval in Equation 4. Similarly, the total mass of material in a pile can be calculated easily using D_{eff} directly without the need to make further allowances for variation of density with depth.

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NEAR SURFACE COMPACTION UNDER GRAZING OF ANNUAL AND PERENNIAL FORAGES*

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BACKGROUND

Soil compaction was defined by Gupta et al. (1989) as the compression of unsaturated soils, causing an increase in bulk density. Many researchers have reported soil compaction by grazing animals (e.g. Warren et al., 1986; Chanasyk and Naeth, 1996). However, few researchers have examined the influence of grazing intensity on soil bulk density for different forage types under the same soil and climatic regime. Since the objective of most grazing management practices is to maximize livestock production per unit area while maintaining sustained forage resource, using annual forages as supplemental pastures may be an option for some managers. Generally the effect of annual cultivation of these forages on soil bulk density, in conjunction with grazing, is unclear.

The objective of this study was to assess near-surface bulk density under different forages and grazing intensities at a site in central Alberta. It was hypothesized that bulk density would increase as grazing intensity increased. Bulk density was expected to be higher under perennial forages than under annual forages and to increase less under smooth bromegrass than under meadow bromegrass.

MATERIALS AND METHODS

The study site was at the Agriculture and Agri-Food Canada Lacombe Research Center in the aspen parkland. Annual precipitation averages 447.5 mm. Soils at the study site are Orthic Black Chernozems of a sandy loam texture. Slopes average 1 to 3%.

Heavy, medium and light grazing intensity treatments were implemented on a rotational basis throughout the growing season. Grazing was initiated and ceased at different specific target forage heights for each grazing intensity. Four forage treatments with potentially differing abilities to control erosion and produce litter were used. Smooth bromegrass (*Bromus inermis* L.) and meadow bromegrass (*Bromus riparius* Rehm.) were the perennial treatments; triticale (*X Triticosecale* Whitmack) and a triticale/barley (*Hordeum vulgare* L.) mix were the annual treatments. The twelve resulting treatments were arranged in a randomized complete block design within four parallel blocks across an east-facing 3.8% slope.

In this study, near-surface refers to the top 10 cm of the surface mineral soil horizon. Nuclear gauges were used to measure near-surface bulk density and near-surface volumetric moisture simultaneously. Measurements were made at three locations in the middle of each third of the plots. Measurements were made over two growing seasons: 1994 and 1995, and at three times during each year: after snowmelt but before annual cultivation, immediately after cultivation and again in the fall before freezeup. The total number of cow-days of grazing was used as a measure of the compactive effort imposed on the treatments.

RESULTS AND DISCUSSION

In both study years, cow-days under heavy grazing were at least twice those under light grazing, except for the triticale/barley treatments. Similarly, cow-days under perennials were approximately twice those under annuals. Surface volumetric moisture content (VMC) was generally not significantly different among forages, except at the

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beginning of the study. In contrast, VMC was higher in lightly grazed treatments than in the medium or heavily grazed treatments.

Bulk density (Db) was generally not significantly different among forages except at the end of the first growing season. Fewer grazing events throughout the first summer likely kept Db lower under annual forages than perennial forages at all grazing levels.

In all treatments, Db was higher after one season of grazing compared to the beginning of the study. In both springs, with Db averaged over all annual treatments, cultivation only reduced Db 3%. Over the two year study period, Db increased more under perennials than annuals.

Db was significantly different among grazing intensities on all measurement dates after grazing was established, except after cultivation. Generally Db was lower under light and medium grazed than under heavily grazed treatments. The change in Db was most dramatic in the heavily grazed treatments after the first season while the change in Db under both medium and light grazed treatments increased only slightly during this period.

CONCLUSIONS

Grazing increased Db, especially the heavily grazed treatment. Although Db under annual forages was lower than under perennial forages, Db under annual forages increased faster than under perennial forages. Cultivation lowered Db only slightly. Db was lower under smooth bromegrass than under meadow bromegrass, likely because of the former's rhizomatous rooting habit which helped mitigate Db increase in the zone of greatest compaction.

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GRAZING IMPACTS ON BULK DENSITY AND SOIL STRENGTH IN THE FOOTHILLS FESCUE GRASSLANDS OF ALBERTA, CANADA*

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INTRODUCTION

The effects of grazing on soil physical properties depend on stocking density, soil texture, soil water and vegetation type. Increase in bulk density due to grazing is in the range of 10 to 15% and surprisingly independent of initial bulk density (Orr, 1960; McCarthy and Mazurak, 1976; Van Haveren, 1983; Scholl, 1989;). Dormaar et al. (1989) measured an average 14% difference in soil bulk density in the uppermost 6 cm comparing ungrazed exclosures with short duration grazing at the study site. The zone of influence of grazing on soil compaction as measured by bulk density is shallow. Orr (1960) found bulk density of the 0 to 5 cm depth interval was significantly higher on grazed range than inside exclosures at three of four sites. Statistically significant differences in bulk density were found on only two sites in the 5 to 10 cm depth interval and not at all below 10 cm.

Only a few researchers have used penetrometers to quantify grazing effects on soil strength and have tended to concentrate on hoof prints versus non-printed areas at very shallow depths. Scholl (1989), in New Mexico, measured an average 123% increase in soil strength due to trampling, with values varying from 0.2 to 0.5 MPa in the control and from 0.3 to 1.2 MPa in trampled areas. Readings were taken when the cone base reached the soil surface (point depth was 3.8 cm). Weigel et al. (1990) measured an average increase of 28% in post-grazing soil strength on seven dates over two years in Oklahoma. Soil strength ranged from 0.2 to 0.7 MPa in ungrazed areas and from 0.2 to 1.1 MPa in grazed areas and showed signs of reduction between years.

Alberta foothills fescue grasslands are very productive but there is some concern that traditional continuous grazing over the growing season may be leading to soil deterioration due to compaction and increased soil strength. Naeth et al. (1990a, 1990b, 1991) studied non-sloped areas of these grasslands that had been continuously grazed (May through October) since 1949. They found that under heavy and very heavy grazing: live vegetation, litter cover, litter biomass, live vegetation and below-ground organic matter all decreased, while bare ground, penetration resistance and bulk density generally increased, particularly at the soil surface. The objective of this research were to quantify the effects of season-long continuous grazing and short duration grazing systems at both heavy and very heavy grazing intensities on bulk density and penetration resistance of sloped areas.

MATERIALS AND METHODS

The study site is located at the Agriculture Canada Stavely Range Substation in Alberta. Annual precipitation is approximately 550 mm with 40% occurring as snow. May to September precipitation is 230 to 370 mm. Slopes range from 18 to 37%. Soils are generally fertile and well drained Orthic Black Chernozems (Typic Cryoboroll) (Walker et al. 1991). Soil texture to 30 cm is generally clay loam with clay loam to loam below. Organic matter averages 12.8% in the ungrazed control to a depth of 10 cm. *Festuca campestris* Rydb. (rough fescue) dominates the ungrazed and lightly grazed areas; *Danthonia parryi* Scribn. (Parry's oatgrass) dominates the heavily grazed areas and exposed sites with thin soils. There are a variety of subdominant grasses, forbs and shrubs. Under very heavy grazing, *Festuca campestris* and litter were virtually eliminated. *Populus tremuloides* Michx. (trembling aspen) encroached upon lightly and moderately grazed grassland.

Research sites were established in 1988 to contrast long-term continuous grazing, four-year-old short duration grazing and an ungrazed control. Continuous treatments were grazed May through October; short-duration treatments were grazed for one week in mid-June. Heavy (2.4 animal unit months (AUM) ha^{-1}) and very heavy (4.8 AUM ha^{-1}) stocking densities, commonly encountered in the area, were imposed upon both the continuous and short-duration grazing experiments. The short duration treatments consisted of two 30 by 120 m grazed strips and a 10 by 120 m

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ungrazed control each replicated three times, running down slope in a randomized split block design. The continuous treatments with the same experimental design were located approximately 0.5 km from the short duration sites.

Penetration resistance (PR) was measured to a depth of 45 cm four times per year at five locations at each slope position with a hand-pushed, manually-read 30°, 21-mm diameter cone penetrometer in 1988 and a 13-mm diameter cone penetrometer during the remainder of the study. Penetration resistance was recorded at 30 depths with the former probe (every 15 mm to a depth of 450 mm) and at nine depths (0, 2.5, 5, 7.5, 10, 15, 22.5, 30 and 45 cm) with the latter probe. The maximum penetration resistances between 0 to 105 and 0 to 300 mm were reported as cone index in both cases. Surface (0 to 7.5 cm) soil water and bulk density were measured at the time of PR measurement adjacent to each PR measurement spot using a Campbell Pacific Nuclear MC1 surface moisture/density gauge.

For each parameter, significant differences of the means were detected using Analysis of Variance with design following the convention outlined in the SPSS-X User Manual (SPSS 1988) for split blocks. Significant effects were further evaluated using Duncan's Multiple Range Test at the 5% level of significance (Steel and Torrie 1980).

RESULTS AND DISCUSSION

Surface bulk density (0 to 7.5 cm) ranged from 0.74 to 0.91 Mg m^{-3} with values in the control < short duration heavy and short duration very heavy < continuous heavy < continuous very heavy. Several low bulk densities for the continuous heavy treatment in the mid-slope position (possibly due to the large and deep rooted woody vegetation) reduced the average bulk density to near that of the control. Increases in bulk density attributed to grazing over that in the control, averaged across slope positions and ignoring the mid-slope value for the continuous heavy treatment, were 8.7, 10.9, 13.2 and 16.7% for the short duration heavy, short duration very heavy, continuous heavy and continuous very heavy treatments, respectively.

Bulk density increased with grazing by a maximum of 0.24 Mg m^{-3}, notably under continuous very heavy grazing. Surface bulk densities under continuous heavy and short duration heavy grazing were similar, but values were clearly higher under continuous very heavy than short duration very heavy grazing. Time between grazing treatments (51 weeks) likely allowed amelioration by plant growth and the retention of deeper rooted species in the short duration than the continuous treatments.

Cone indices to 105 and 300 mm for 1989 to 1991 were generally significantly different among continuous and short duration grazing treatments, with lowest values in the control and highest in the continuous very heavy treatment. Treatment ranking was identical to that for bulk density. Cone index increased with grazing intensity under continuous grazing but not always under short duration grazing. The lack of a grazing intensity trend for the short duration treatments may reflect the greater rooting depths of plants under short duration versus continuous grazing (Naeth et al. 1991). There were no trends in cone index with slope, for either 105 or 300 mm depth intervals.

A value of 2.0 MPa is often accepted as a threshold potentially limiting to root growth. To 10.5 cm, this value was exceeded on most measurement dates in the continuous very heavy treatment, but only in the other grazing treatments on the last two measurement dates in 1991. In contrast, on only four dates, and only for select treatments was this value not exceeded to 30.0 cm. Penetration resistance is thus potentially root growth limiting at a depth between 10.5 and 30.0 cm. At this site, this is a surprising result given the high organic matter content of the soil.

For all treatments, in a given growing season, cone indices to 30.0 cm were highest in October. However, these high fall values were ameliorated by soil water recharge due to snowmelt. Averaged across slope positions and two winters (1989/1990 and 1990/1991), the reduction in cone index to 30.0 cm was 52, 40, 29, 30 and 28% for the control, short duration heavy, short duration very heavy, continuous heavy and continuous very heavy, respectively, with little difference between years. The higher reduction in the control is likely due to greater snow trapping and higher snowmelt infiltration in that treatment (Naeth and Chanasyk 1996).

Slope-averaged PR with depth was considered for two dates in 1991: 15 May when soil water was highest and 7 August 1991 when soil water was very low. PR on 15 May generally increased with depth for all treatments and there was a clear treatment trend of increasing PR magnitude at all depths: control < short duration heavy < short duration very heavy < continuous heavy < continuous very heavy. PR on this date was less than 2.0 MPa for the control and short duration heavy treatments at all depths. Moving from the short duration very heavy to continuous heavy to continuous very heavy treatments, PR exceeded 2.0 MPa at depths of 45, 30 and 22.5 cm, respectively,

indicating the influence of grazing on PR and the presence of potentially root-limiting PRs nearer to the surface as grazing intensity increased and as the grazing system changed from short-duration to continuous.

PR on 7 August 1991 also increased with depth, but more steeply than on 15 May. Under dry soil water conditions on this date, PR was similar for the control, short duration heavy and short duration very heavy treatments below 10 cm, exceeding 2.0 MPa for all depths > 15 cm. Trends in the two continuous grazing treatments were distinct from the other three treatments and from each other, with PR for continuous very heavy exceeding that for continuous heavy at all depths. In both treatments, PR was > 2.0 MPa at all depths greater than 5 cm and > 3.0 MPa at depths greater than 22.5 cm. PR increased between May and August at all depths for all treatments, likely due to a decrease in soil water, as bulk density did not change appreciably over this period.

CONCLUSIONS

Negative impacts of grazing on soil were evidenced in both bulk density and penetration resistance. Even short duration treatments affected these soil properties, with similar effects for both heavy and very heavy intensities. Distinction between heavy and very heavy continuous grazing treatments was clear for both bulk density and penetration resistance, with the very heavy treatment having the greatest effect. Parameter values were always lowest in the spring after snowmelt and highest late in the growing season, reflecting the soil water regime. Treatment rankings were identical for both bulk density and cone index, but cone index was a more sensitive indicator of the grazing effects than bulk density.

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OCCURRENCE AND GROWTH OF GULLIES ON MINE DISTURBED LAND*

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SUMMARY

Gullies are erosional features found in both natural and reconstructed landscape. They are indicators of geomorphic maturity and therefore represent a valuable tool for assessing the performance and sustainability of mine disturbed land following reclamation. Some types of gullies are associated with instability, rapid erosion, and accelerated landform deterioration. Other types are inactive, self-healing and/or subject to gradual change, consistent with the aims of sustainable reclamation. Both types of gullies occur on mine disturbed land following reclamation or premature abandonment. An inventory of gullies at a sand disposal area near Fort McMurray was conducted to identify the types of gullies, their size, associated erosion rates, and self healing tendency. The results of this analysis lend support to the current method of reclamation and provide guidance for future modifications to closure plans. The data can be used to develop a strategy for mine closure to minimize the risk of rapid landscape evolution by gullying. A system of annual monitoring of gully shapes and sizes is being conducted to confirm long term sustainability.

BACKGROUND

Suncor Inc. has built numerous tailings storage facilities at their oilsands mine in Northern Alberta, 30 km north of Fort McMurray. The facilities are composed of sand dykes which presently contain a combination of fine tailings, other mine waste materials and water. Ultimately, upon mine closure, the fine tailings will be replaced with Consolidated Tailings (CT) which is a solid mixture of sand and fine tailings, to enable development of mainly dry landscape.

The oldest sand dykes on the Suncor mine site are located at Pond No. 1 which is contained by a sand perimeter dyke known as the Tar Island Dyke (TID). Construction of the TID began in the late 1960's and is presently close to completion. The sand dyke has been progressively reclaimed and therefore vegetation at the lower reaches of the dyke have reached a 25 year maturity.

The TID is composed mainly of sand and is presently about 100 metres high at an overall slope of 3H:1V. The sand is highly permeable with an effective infiltration rate of over 70 mm/hour. The near surface soil permeability was measured by Guelph Permeameter to be about 1 to 6×10^{-3} cm/sec. The D_{50} of the sand ranges from 0.20 to 0.25 mm. The sand contains 2 percent to 8 percent fines (minus #200 sieve).

Reclamation of the sand dykes includes a 15 to 20 cm cover of topsoil composed mainly of peat. Formerly, revegetation involved planting of agronomic grasses as well as trees but the present method of reclamation involves growth of natural species enabled by direct placement of peat. Most of the dyke area is covered by topsoil and supports vigorous growth of grasses, natural species and trees. Some areas have little or no topsoil cover as a result of erosion during construction and covering by windblown sand.

In 1995, Suncor Inc. commissioned a study to examine the erosional sustainability of their reclaimed areas. The study was commissioned to provide a sound basis for reclamation planning and ultimately to provide evidence that the reclamation system is sustainable over the long term.

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As part of this study, Suncor Inc. commissioned an inventory of the occurrence, character, frequency and stability of gullies on the TID. The inventory included classification of the gullies and an assessment of any self-healing characteristics. Suncor Inc. also commissioned the selection, survey and monitoring of fifteen gullies to provide a long term assessment of their growth or stabilization. The monitoring data is intended to provide a basis for acceptance of the sustainability of the TID by government regulators.

METHODOLOGY

Tar Island Dyke (TID) has been subject to a range of environmental conditions since reclamation began 25 years ago. These have resulted in some gullying, particularly at unreclaimed areas and freshly reclaimed areas. A survey was conducted to provide a basis for assessing the frequency and stability of the gullies. The survey included the number, density, location, size, type, cause and growth/stability of gullies. An inventory of gully data was developed to determine the prevalence, severity and long term continuation of gullying. It was configured to provide a basis for assessing the self-healing character and progressive growth of gullies.

A representative sample of gullies was selected to provide a sound statistical basis for developing an inventory of gullies. The inventory was based on an area of 23 hectares which represents about 19 percent of the total surface area on the outside face of TID. The total area was divided into eight strips, each approximately 100 metres wide, located at 500 metre intervals. They extended from the crest of the dyke, down to the toe of the dyke. Each strip was divided into blocks from the toe to the crest of the dyke.

In addition to the inventory of gullies in the representative strips, fifteen gullies were selected for more detailed investigation and future monitoring. The fifteen gullies were selected to represent a range of gully sizes (five small, five medium and five large) and a variety of gully types (self-healed, no growth and active growth). Detailed investigation included a survey of gully cross sections with local benchmarks installed along each cross section so that gully growth may be tracked over time.

SURVEY, INVENTORY AND MAPPING

A detailed inventory of all gullies identified during the study was presented on a spreadsheet which indicated the following characteristics of each gully:

- Gully location;
- Gully length, width and depth;
- Volume of eroded material;
- Existing vegetation cover;
- Assessment of possible causes;
- Assessment of erosion activity (self-healed, growth, etc.;
- Repair efforts and effectiveness;
- Photograph record;
- Commentary.

A statistical summary of the gully inventory assessment was also prepared. The number of gullies in each block were summarized by cause of erosion and by level of erosion activity. The number of gullies in each category of cause, type and eroded volume was summarized for each block. This provided a spacial analysis of gullying on the TID. The character and cause of gullying was summarized by location, from the earliest reclamation at the base of the TID to the most recent reclamation near the crest of the dyke.

The locations of the 15 gullies selected for detailed assessment were mapped. The surveyed cross sections, photographs and details of each gully were presented on separate drawings. Future surveys may be carried out using the benchmark information provided on the drawings.

CAUSES OF GULLYING

The spacial distribution of gully density indicated a greater number of gullies within Strips A, B and C, located on the south end of the TID, than at other locations. This may be indicative of improved soil moisture availability to support vegetation on the north end of TID, where aspect is more favourable to water conservation. The south end of TID has a southerly exposure resulting in greater solar radiation, more drying, and possibly more loosening of surfical soil by freeze-thaw.

The three most common causes of gully development observed at the TID are as follows: no vegetation present when the gully first developed (29 percent of gullies identified); no existing vegetation (39 percent of gullies identified); and terrace ponding (22 percent of gullies identified).

There were other minor causes of gullying. A high phreatic surface and groundwater seepage discharge at the toe of TID caused 6.5 percent of the gullies. Such gullies are characterized by a cirque-shaped head. The channel formation process for this type of gully has been described by Schumm, *et al* (1995). One gully was caused by a pipe outfall and two gullies were caused by uneven grading of the TID slope.

Gullies exhibiting the greatest growth were found near the top of TID, where very little or no reclamation existed. This area of the TID was built most recently and the extensive gullying reflects immature vegetation and pre-reclamation conditions. Many large gullies and rills formed on the exposed sand surface as a result of the absence of a protection cover and root mass. Sand dunes caused by wind erosion on the unreclaimed sand surfaces near the crest have formed on the lower berm. These dunes have caused flow obstructions and ponding on the lower berms and this may have caused many of the gullies on the lower slope.

Active gullies exhibiting progressive growth occur at various locations on TID. Active gullies on the recently reclaimed area are attributed to the absence of an effective vegetative cover, reflecting pre-reclamation conditions. Most other active gullies are attributed to terrace ponding (i.e., flow concentrations created on the TID berms).

A self-healed gully is one in which there is no active erosion or growth as a result of an armour layer or the growth of vegetation in and alongside the gully. The concept of self-healing has been described by Ireland, *et al.*, (1939) in a description of the stages of gully development. "Stage 3 is a period of healing. Slopes of the gully walls are reduced by weathering, slope-wash and mass movement; plants are established on the lowered slopes, and vegetation gradually brings about a healing of the gully. Stage 4 is a period of stabilization, and it is characterized by the slow development and accumulation of new soil over the old scarred surface." More recent discussion of this phenomenon is provided by Schumm, *et al.*, (1984). Self-healed gullies are predominantly located near the bottom of the TID. Self-healed gullies comprised 37 percent of all gullies identified.

Self-healed gullies were analyzed to identify the cause of the self-healing mechanism. Self-healing is often associated with the development of a gravel armour layer as a result of the removal of fines by erosional forces which are insufficient to remove the larger size material. However, the self-healing process on TID is different. Vegetation develops in the gully to reduce erosion. Vegetation develops naturally in gullies, probably as a result of improved moisture conditions inside the gully The gullies collect more water than adjacent areas because of their larger collection area and because wind blown snow deposition in depressional areas. At many locations, the vegetation in the gullies was observed to be thicker than the vegetation adjacent to the gully.

RATES OF EROSION AND GULLYING

The total volume of gully erosion on the 100 metre strips is approximately 5900 m^3, based on the calculated volume of measured gullies. This equates to an erosion per unit area of 26 mm, or an average of 1.3 mm per year over the average 20 year life of TID.

Assuming this erosion rate is representative of long term conditions, the total erosion over the entire dyke in 1000 years would be 3.1×10^6 m^3, which is equivalent to a total depth of erosion of 1.3 metres over the entire surface of the TID. This erosion volume and depth shows that TID has been subject to moderate to high rates of erosion. However, most of the gullying is representative of immature reclamation conditions during the early years immediately after construction. Gullying at the more mature reclaimed areas is much smaller than calculated above.

A useful follow-up to this gully mapping study is monitoring the selected fifteen gullies whose cross sections have been surveyed. It is very likely that future erosion will be far less, especially at well reclaimed areas. Such data may provide a sound basis for confirming the sustainability of TID and also for regulatory certification.

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